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Metal Progress

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METAL PROGRESS

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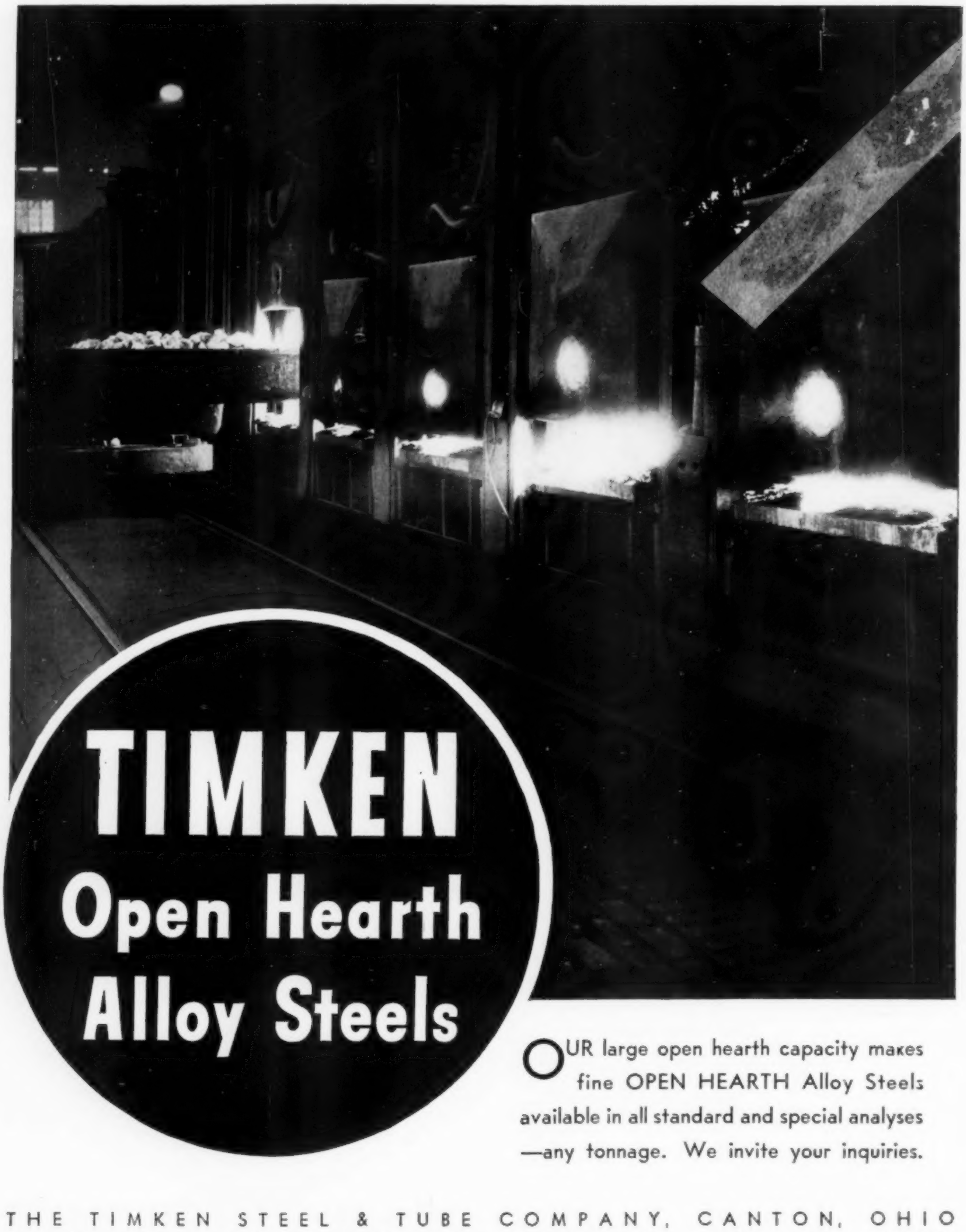

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CARBURIZING PRACTICE

By John F. Wyzalek
Chief Metallurgist
Hyatt Bearings Division
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Harrison, N. J.

THE ART of carburizing is very old, at least 1000 years. We have the evidence of old Japanese swords, carburized so the cutting edge is hard. The *science* of carburizing is relatively new, since it was only in 1786 that carbon was identified as the element being absorbed by the metal in the process.

The technical purpose of carburizing is perhaps best explained by quoting the National Metals Handbook, which states: "The purpose of carburizing is to obtain, through the penetration of carbon in the article subjected to the process, an outside portion high in carbon, generally known as the 'case' and which gradually decreases in carbon content toward the center of the piece. After suitable heat treatment, this case is hard and resistant to wear."

The practical purpose of carburizing is either to effect lower manufacturing costs while substituting low carbon steels for medium and high carbon steels wherever possible, or to provide a steel with a composite of a hard surface to resist wear and a tough, ductile center to withstand shock.

Carburizing Compounds — Since the aim of the process is to enrich the surface layers of steel with carbon, the material used to do this, that is, the carburizing compound (whether solid or gas) must have a ready supply of carbon. Hundreds of formulas have been patented, and every old-time workman has his own favorite. Most of them are complex and contain unstable organic materials, such as leather and bone chips, and their behavior during repeated or prolonged heating is quite variable, and hence they are unable to produce that uniformity in finished part which is absolutely essential for modern machinery.

Numerous satisfactory compounds are now available, commercially, under proprietary names. Probably the widest used may be classified as a "charcoal-coke" type, a mixture of hardwood charcoal and petroleum coke, "energized" with barium carbonate, calcium carbonate, and sodium carbonate. This may be readily distinguished by its angular fragments, porous and fairly uniform in average size. Another used extensively may be called the "pellet" type, wherein the carbonaceous ingredients and chemicals are ground, intimately mixed with a binder, and formed into pea-sized pellets. Still another may be called "hydrocarbonated bone black," and is for sale either with or without chemical energizers; it has a particle size approaching sugar or sand. Finally should be mentioned the home-made compound noted in National Metals Handbook: 60% hardwood charcoal, 25% petroleum coke, 10% barium carbonate, 5% calcium carbonate, which can be highly recommended, it being used extensively in plants making automotive parts.

If a part is packed in angular fragments of charcoal, it is obvious that actual contact between metal and solid carburizer occurs only here and there, yet the part is uniformly carburized. The accepted explanation for this fact is that a carbonaceous gas is the carrier of carbon from solid compound to the exposed surface of the metal.

It is also commonly believed that the alkaline carbonates (or "energizers") supply the needed carbon monoxide gas when heated, and regenerate themselves on later exposure to the air by absorbing carbon dioxide from it. My experience with this type of carburizer indicates that the material energized with barium carbonate is the most desirable, due to the fact that the character of case produced is found to be more uniform, both from the standpoint of carbon content and depth of penetration.

Experience has also convinced me of the necessity of using carburizers in certain definite proportions of new and old material; this effects economy, greater uniformity, and less shrinkage. The general practice for charcoal-coke carburizers is to use between three and four parts of old to one part of new material. In other forms of carburizer, such as pellet or bone black types, the additions of new are appreciably less, generally being made only to compensate for the losses incurred in handling and use.

Life of Compound — The comparatively large amount of new charcoal-coke carburizer added at every re-use needs some consideration in view of the idea that the energizers should regenerate on rest and exposure. Our own experience and laboratory research on compounds energized with barium carbonate indicates that barium carbonate when subjected to carburizing temperatures transforms to barium sulphate and it remains in that form on repeated runs. Additions of new material are made primarily to compensate for losses in handling and also for screening losses, the latter operation being performed for the purpose of eliminating ash. Normally, in a manufacturing unit such as ours, there is very little carburizer discarded of what may be called usable quality, the major portion of the reject being screenings which could be, of course, a mixture of ash, energizer, and very fine particles of coke and charcoal, and the new material added merely compensates for these losses.

The method of impregnating the carburizer with energizer is important, and proprietary methods of doing this probably comprise the major difference between compounds of the charcoal-coke type now on the market. Special claims by salesmen as to unusual efficiency of this, that, or the other chemical should be investigated before believing. For instance, results so far obtained in a little work we have done on ferrosilicon, do not bear out claims made in respect to the speeding-up action of ferrosilicon at high temperature without causing an excessively high carbon case. On the other hand, we find that compounds energized with sodium carbonate give higher carbon cases and barium carbonate and calcium carbonate lower carbon contents, in the order mentioned.

Desirable features in a carburizer are (*a*) rapid penetration with desired carbon content in the case, (*b*) lasting qualities, so as to insure uniform carburizing performance, (*c*) low specific gravity, that is, minimum weight per cubic foot, so as to give maximum volume per ton pur-

A Small Pile of Carburizer of the Charcoal-Coke Type (Courtesy Case Hardening Service Co.)

chased, (*d*) minimum shrinkage of carburizer when subjected to carburizing temperature, thereby enabling the containers to be filled to maximum capacity, (*e*) good thermal conductivity, to aid rapid uniform heating of the charge, (*f*) freedom from impurities which would contaminate the steel either through absorption or deposition. Comparative ratings of the three principal types of commercial compounds are approximately as shown in the table.

With the above thoughts in mind, compound would be bought by the careful purchaser on the following bases: Chemical composition, indicating desired percentages of energizers, coke, or charcoal, if present; limitations should be placed on undesirables such as moisture, sulphur, and inorganic matter. From a physical standpoint, carburizer should be held to a definite particle size, a definite maximum weight per unit of volume, and be limited to the amount of shrinkage experienced under a heating cycle and routine agreed upon by both parties.

Characteristic	Hardwood Charcoal + Petroleum Coke	Pellet	Hydro-carbonated Bone Black
Rate of penetration	High	High	Low
Carbon concentration	0.90 to 1.25%	0.90 to 1.25%	0.70 to 1.00%
Lasting qualities	Good	Good	Very good
Specific gravity	Low	Mean	High
Shrinkage	Fair	Good	Very good
Thermal conductivity	Very good	Good	Fair
Freedom from undesirable impurities	Good	Good	Good

Packing and Containers

To insure satisfactory carburization it is extremely important to pack the product in a proper manner, taking into account the necessary spacing of parts to effect uniform heating. Allow for shrinkage of carburizer by not packing the parts too closely to the top of the container. This shrinkage would be greater in carburizers of the charcoal-coke type and less in the pellet and bone black types. However, it is always advisable to allow for some shrinkage in order to prevent exposure of the top layer of parts.

Amount of compound between pieces, and between pieces and container, will naturally vary with the operating conditions and metallurgical requirements as applying to the finished part. For depths of case of $\frac{1}{16}$ to $\frac{1}{8}$ in., a minimum distance of $\frac{3}{4}$ to 1 in. is generally necessary between pieces (and between pieces and container) to insure satisfactory carburization at minimum cost. Our experience has indicated that the method of promiscuous loading of small parts into a container and actually allowing them to touch each other is unsatisfactory. A layer of carburizer should be spread evenly across the box, then some small parts scattered thinly over the top, then another layer of carburizer, and so on.

Particle size of compound also plays a part in the efficiency of a carburizer. Up to a certain point it is unquestionably advisable to encourage "ventilation" or circulation of carburizing gases inside the container by using medium size particle carburizer. We find that a fine size compound does slow down carburization to some degree — this is one reason for screening out all of the fines.

Containers should be viewed as something more than just a box to hold carburizer and parts. Heat resisting alloy containers of one sort or another are almost universally used. Long life does not tell the whole story. Due to their non-scaling characteristics they insure uniform heating. This would not be true with containers made of iron or steel which, after a few runs, would scale considerably (and non-uniformly) and thereby conduct heat at a different rate in the thin and in the thick regions, which in turn would seriously affect the temperature uniformity in the contents and thus vary the depth and character of carburized case. Another important requirement in connection with carburizing containers is that they be of proper design to be conducive to uniform heating of the charge and also to insure satisfactory service through minimizing warpage and cracking.

The common cause of failure of alloy containers is warpage and cracking, which I believe is brought about by the repeated expansion and contraction. We have found it possible to flatten containers, slightly warped, by heating to approximate carburizing temperature, then applying mechanical force to straighten. We have not found welding practical on cast boxes, although on sheet metal boxes this has been done satisfactorily.

Obviously, furnace gases must not penetrate into the box; if they do the carburizer will burn and cause local overheating which will ruin the work. This does not mean that box covers shall be air and pressure tight at all temperatures, al-

though they should be "reasonably" so. In other words, a badly warped cover should be scrapped; a fairly close fit is satisfactory and the joint does not need to be luted with some compound (which would probably crack during the heating cycle, anyway). Expanding gas must also escape.

Types of Furnaces

Various types of satisfactory furnaces can be classified in two general types, namely, batch type and continuous type, with several recognizable varieties in each. The oldest batch type is merely an oven; car-bottom furnaces are of this type as are also the furnaces which have a rotating muffle of heat resisting alloy. Continuous furnaces are generally long tunnels through which the work is pushed, and frequently are "counter-flow," that is, have two lines of work, side by side, progressing in opposite directions. Rotary hearth or turret-type furnaces are also of the continuous type, and rotating muffles can obviously be converted to this type by automatic feeding and discharge devices.

For production on a large scale of medium or large sized parts, the continuous type of furnace would unquestionably prove of greatest advantage, due to its low operating cost per part carburized. For small parts, regardless of volume, the rotary batch type furnace would very likely be the most desirable. The batch type furnaces, and in particular the oven type, would be the most suitable furnaces for carburization of reasonably small quantities of medium and large size parts. Experience indicates that the continuous type gives the greatest uniformity in case, perhaps mainly due to the fact that every container is subjected to identically the same treatment.

Batch type furnaces are generally loaded with boxes one at a time by means of hand trucks or forks attached to overhead hoists or cranes. In order to induce the proper circulation of heat, it is, of course, necessary to resort either to extensions, such as legs at the bottom of the pot, or to rails on the hearth of the furnace, whereby the main portion of the pot itself is several inches above the hearth level.

John F. Wyzalek

Member American Society for Metals, Active in New York and New Jersey Chapters for Many Years. This article is from a talk recently given to his own home chapter. (Photo by Bachrach)

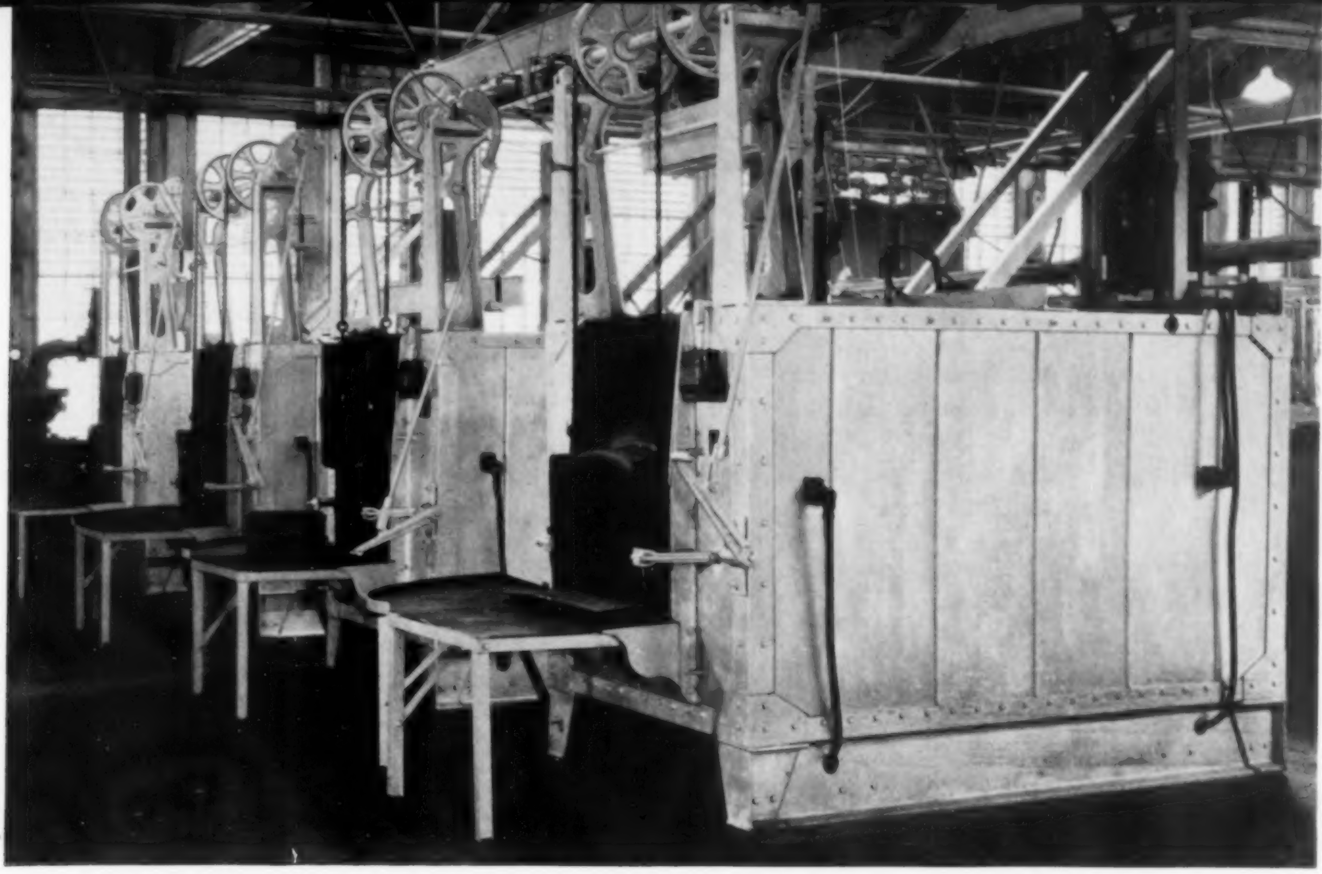
Oil or gas is used very extensively with satisfactory results, this being particularly true in the large furnace installations, although some notable installations are electrically heated. However, for small furnaces such as rotary and oven types, gas has been found to be more suitable than oil due to its ability to heat the charge more uniformly. Coal is not used very extensively today, mainly because of inability easily to maintain uniform temperatures in the carburizing chambers.

In order to obtain satisfactory carburization, from the standpoint of character and depth of case, our experience indicates an over-all variation of 25° F. in the zone wherein the carburizing containers are charged is permissible. Deviations beyond this limit cause, I find, sufficient non-uniformity in either character or depth of case to be objectionable. Further, from the standpoint of uniformity of control, after establishing a definite temperature, deviations of 10° plus and minus would be recognized as good practice.

Heating and Cooling

The temperature to be used for carburization depends largely upon the requirements of the finished part. Broadly speaking, however, for depths of case ranging from $\frac{1}{32}$ to $\frac{1}{8}$ in., temperatures between 1650 and 1750° F. are generally used. On the other hand, for depths below $\frac{1}{32}$ in. temperatures between 1375 and 1450° F. are more suitable. Experience has indicated that the higher the temperature, the more rapid the penetration and the higher the carbon concentration at the surface of the carburized case. The reverse would hold with lower temperatures. Therefore, in practice, to effect satisfactory product at minimum cost, it is necessary to develop the maximum temperatures at which the desired carburized case is obtained, with the objectionable conditions held within acceptable limits.

The top temperature of carburizing is limited by excessive grain growth



Four Electrically Heated, Batch Type Carburizing Furnaces (George J. Hagan) in Brown and Sharpe's Plant. Small carburizing box may be noted on the run-out at second furnace

in the steel and by the lasting qualities of the carburizer. Also the higher the carburizing temperature, the higher the carbon concentration at the surface. For a particular part, satisfactory results depend not only upon the hardness at the exterior, but also upon the physical characteristics of the entire case, both from the standpoint of ductility or brittleness and gradation of carbon and hardness from the surface to the core.

Very frequently, especially when carburizing at temperatures around 1700° F., the last part of the run is at an appreciably lower temperature so as to diffuse the carbon in the case. Such diffusion of the carbon gives better wear resistance of the parts and minimizes checking in grinding of the hardened parts.

Sometimes small, spindly or flat parts (such as sewing machine details) are carburized with relatively shallow cases, approximately $\frac{1}{64}$ to $\frac{1}{32}$ in. It is then impossible to use any other but temperatures in the neighborhood of 1400° F., since higher temperatures would distort the parts and at the same time make it impossible to produce a case within close limits so as to insure a hard surface with a ductile core.

Not so very long ago it was standard practice to cool the parts in the pot, screen out the compound for re-use, and then give the parts a double heat treat, one to refine the core and the other to harden the case. Since it has become possible to purchase regularly alloy steels of the fine grain type (that is, of grain size 6 or finer, in accordance with the American Society for Testing Materials standard — which are actually steels which do not coarsen at normal carburizing temperatures), it has been found possible to quench direct from the pot. This direct quenching can be applied either as an operation replacing the so-called "first heat" normally given for refining the core, or can eliminate entirely all subsequent hardening operations.

Correct temperature for such direct quenching from the pot is determined by trial and by actually determining the temperature of the parts through the use of optical and contact pyrometers. When the correct furnace practice has been established, or the correct time interval after withdrawing the pot from a hot oven has been found, the metallurgist can establish a practice which insures repetition of the desirable condition in production.

Direct quenching with certain steels, particularly nickel-molybdenum S.A.E. 4615 and nickel-chromium S.A.E. 3115, is frequently more desirable than the reheat method, due to the fact that equally as good and sometimes superior physical properties are obtained in the finished part at a much lower cost. Of course, to accomplish satisfactory results, grain size controlled steel must be purchased, and the parts must be of such shape and size as to quench direct without damage.

(Continued on page 64)

NODULAR TROOSTITE

its structure

By Francis F. Lucas
Member of Technical Staff
Bell Telephone Laboratories
New York

IN MARCH, 1934, Prof. Charles Y. Clayton published a note in METAL PROGRESS in which he voiced the need for a publication of photomicrographs, prepared at high, medium, and low power, showing the normal structures in carbon steel, especially troostite and sorbite. Shortly thereafter the editor wrote to me, suggesting that I might have some negatives available which would conform to these requirements, especially since I had already discussed the nature of troostite in some former publications. The latest of these was "Structure and Nature of Troostite", presented before the World Engineering Congress in Tokio in October, 1929, and reprinted in Bell System Technical Journal in January, 1930.

These articles had been written before we had received the precision high power metallographic apparatus described at the annual convention of the Society a year ago in Detroit. It seemed proper, therefore, to study some typical troostite with this new equipment, and see whether it would verify or disprove some of our old assumptions about conditions existing beyond the range of resolution of the equipment available a few years back.

We also used our new abrasive for final preparation of the specimen. This method of refining abrasives will soon be published.

Possibly the student might expect that I would send three micrographs, one at 200 X, one at 1000 ×, and one at 4000 ×, which would prove to be "classic" structures of troostite, and he will be somewhat chagrined to observe an assortment such as I have included. The one on page 25 at 200 × is the only one which will fill any such bill, and unfortunately it does not tell very much about the nature of troostite. As resolution is raised to the highest powers, the dimensions of the field decrease and the complexity of the structure is developed.

Photographs on pages 26 and 27 show the variations in structure which occur in a transverse specimen of a ½-in. round hot rolled rod of slightly hypo-eutectoid composition. It is typical of a hot rolled rod such as may be secured almost anywhere from a reputable steel maker. The rod was photographed as received from the warehouse, and received no heat treatment whatever in the laboratory. I have chosen such material because of its practical utilitarian nature, rather than some specimen which I might heat treat under laboratory conditions and which many would probably regard as of academic interest.

The structures shown may be defined as troostite. In the first picture, taken at 200 diameters, as much gradation in tone as possible has been developed. Unless the specimen is carefully prepared the structure would appear almost black and devoid of detail under the conditions of this photograph.

While this particular specimen after conventional etching would be dark and almost com-

pletely structureless at moderate magnifications, almost anyone with a little care and experience will find samples of quenched steel wherein some well-developed pearlite can be discovered amongst the unresolved troostite. The hasty conclusion might be to assume that troostite is pearlite. This cannot be affirmed or denied without much closer scrutiny.

The six views on page 26 at 1000 × show the variations in structure which occur throughout the same field as shown at low power on this page. These micrographs were taken with a very high aperture lens and show remarkable resolution. The student will note, however, that only the relatively coarse structure or well-laminated pearlite has been fully resolved. Some grains are white and practically structureless; others appear very faintly granulated or striated and others are granulated and quite dark. Here and there a little excess constituent (ferrite) appears.

In some discussions on the nature of martensite printed in *Transactions* of American Society for Steel Treating in 1924 and 1929 I expressed the viewpoint that the first indications of precipitation of excess constituent from a solid solution were to be observed under the microscope by a slight cloudiness or change in color of the uniform solid solution, and further stages in the separation of the phases are observed by an increasing cloudiness or granulation, even if unresolvable. With this in view, the ultimate structure of troostite (or perhaps it would be better to say, the first stages in the formation of troostite) may be sought for in the white structureless or cloudy grains shown in this group X-211.

The next series of six photomicrographs on page 27 at 4000 × were therefore of representative areas of the field which at 1000 × are clear or exhibit only an increasing cloudiness. They were taken with the monobrom-naphthalene optical system of 1.60 numerical aperture and the very highest resolving power. Even the white structureless areas in the photographs at 1000 × show incipient stratification. In other areas, which, viewed at 1000 ×, appear a little more granulated or striated, the structure shown at 4000 × is actually a little further advanced in the process of forming laminated pearlite. The figures in this second group (X-212) are arranged from A to F to show progressively these changes in stratification.

It therefore becomes apparent that pearlite forms out of the troostite, and with the highest order of resolution the very incipient stages of stratification can be picked up. In this state stratification of carbide is just starting, and sharp, distinct outlines of the plates are not to be expected. Only when the process has advanced to the state of well-defined plates can one get sharp outlines; otherwise only a gradation in contrast is observed.

It is truly remarkable that this new lens system will break up a structureless white field to reveal the very early process of separation of ferrite and carbide. The improvement over older equipment cannot be measured in per cent, or added lines of resolution. It is a matter of being able to see things by one method and not to see them by another!

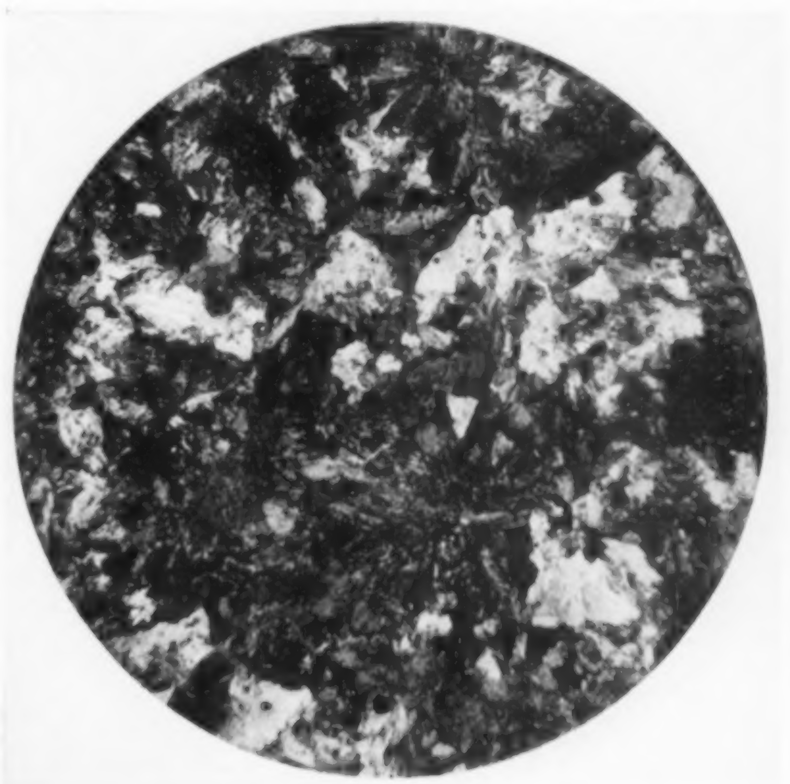
* * * * *

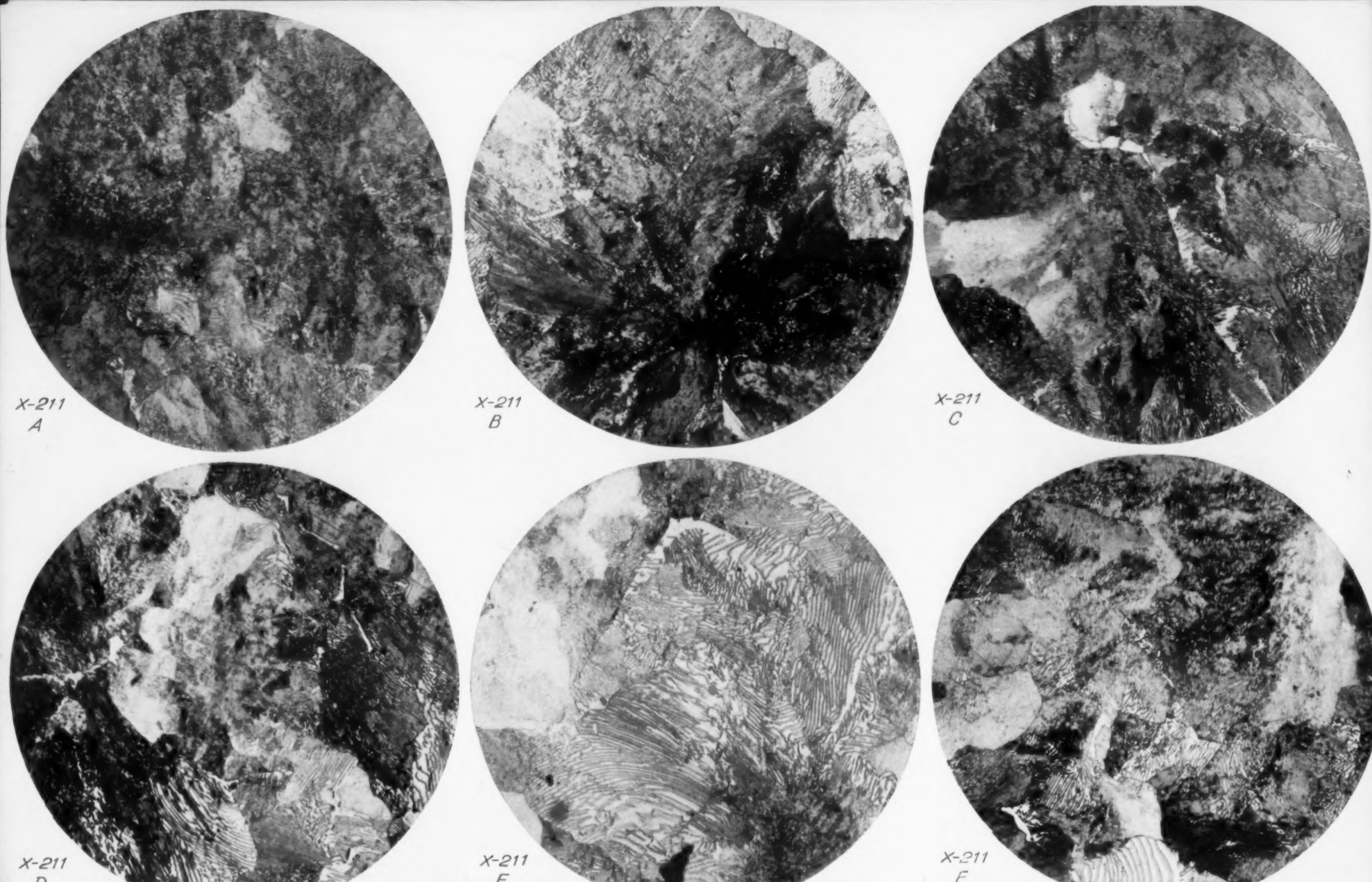
Some notes may be taken from former publications on the origin and nature of troostite, to present views which have been given further substantiation by these recent microscopic studies.

If a small specimen of medium or high carbon steel is quenched in water or oil, it possesses a microstructure of martensite needles and scattered particles of troostite. The relative proportions of the two depend upon the rate of cooling during quenching. This type of troostite formed on cooling is known as nodular troostite.

These nodules develop from innumerable nuclei throughout the austenite and martensite matrix, in most cases identifiable as an inclusion, a void, or a sharp corner in a grain boundary. In samples where the proportion of troostite becomes higher and higher, finally the whole mass

Troostite in Hot Rolled Rod of Commercial High Carbon Steel. Etched for maximum contrast in tone, nodule to nodule. Magnification 200 diameters

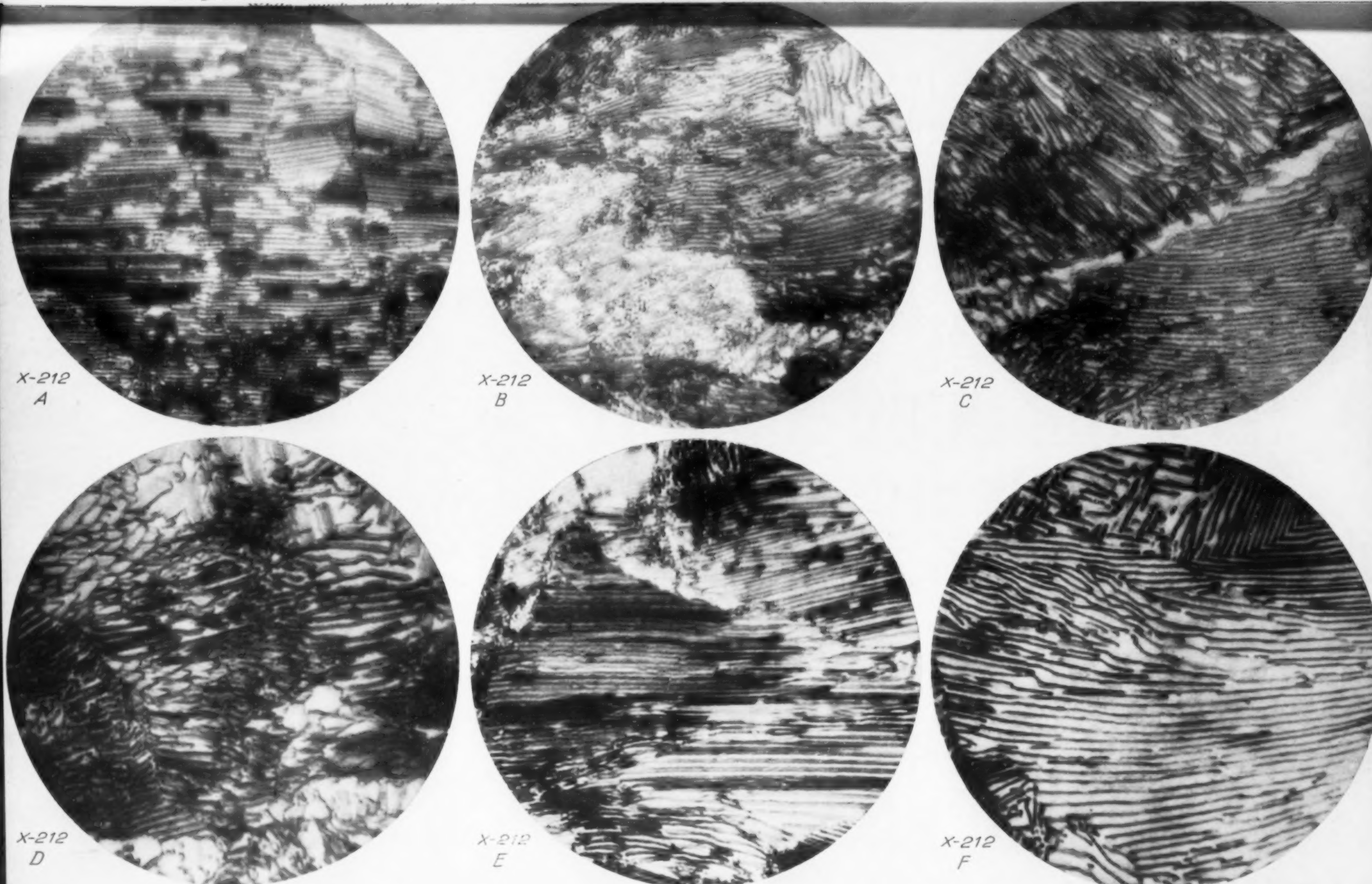




F.F. Lucas

Representative Portions of Troostitic Field Shown on Page 25, Now Magnified 1000 Diameters

Representative Portions of Troostitic Field Shown on Page 25, Now Magnified 1000 Diameters



Progressive Changes in Stratification of the Structure of Troostite

Monobrom-naphthalene optical system, N.A. 1.60, magnification 4000 ×. White structureless areas in the views on opposite page now show incipient stratification. As the cloudiness in the areas at 1000 × increases the clarity of the laminated structure at 4000 × improves

seems to be composed of nodules, some spherical in shape but many deformed due to mutual interference and to irregularities in growth. A selectivity or preference in crystal habit probably prevails for crystallographic planes since spines, branches, and interconnected crystallites may be found occasionally. In reality these are poorly formed nodules, growth in some one or more directions having been arrested.

When one of the globular-shaped crystal masses which has developed under favorable conditions of growth is sectioned in such a way as to divide the mass along a plane passing through the center, the nucleus is found at the center and fan-shaped grains extend from the center toward the outside.

Each of the fan-shaped grains is a separate crystalline unit, for if a nodule of troostite is revolved about the optical axis of the microscope, these very small fan-shaped grains display orientation phenomena — that is, change through a cycle of color and brightness. (This is exactly the same thing as observed in polyhedral grains in a pure metal when revolved about the optical axis of a microscope while being kept under observation at 100 or 200 diameters magnification.) Of course in nodular troostite the grains are fan-shaped and quite small, making it desirable to carry out the observations with an oil immersion lens which will yield high magnifications.

While the best optical equipment and technique available ten years ago showed some of these radial grains to be structureless, and of the appearance of a solid solution, the above appearances indicated stratification of some form. It was also quite evident that if the entire mass of a carbon steel passes through the nodular troostitic stage, this constituent must contain carbide or carbon in some form.

Nodular troostite (or troostite that forms on quenching, rather than on tempering) is not like martensite in forming along the octahedral crystallographic planes of the austenite. It has a new crystalline orientation of its own. Evidently the slower rate of cooling is favorable for the freshly transformed alpha iron to re-orient itself about some convenient nucleus.

Francis F. Lucas

Needs little introduction to ASMembers, as he has addressed many Chapters on subjects relating to microscopy, to which he has contributed brilliantly

To quote further from my 1929 paper, "Structure and Nature of Troostite":

"The question naturally arises as to whether the steel in its transition from austenite to pearlite first develops a needle structure (martensitic) and then this, in turn, is replaced by a nodular (troostitic) one.

"Some light was thrown on this angle of the problem by a high power examination of an iron-carbon alloy. The carbon content was 2.65% and by quenching small pieces from very high temperatures, polyhedral grains of austenite containing martensitic needles and troostitic nodules were found to occur. Both constituents were found to occur in the same grain and both seemed to be entirely surrounded by austenite. Had the needles formed first and the nodules developed from the needles, one might expect to find some nodules with untransformed needles sticking out around the boundaries of the nodules. This was found not to be the case. The boundaries of the troostitic nodules are always sharply defined.

"If a specimen of commercial tool steel is heat treated (quenched at the proper rate) to produce some troostite in a martensitic matrix, and this specimen is then tempered, one might expect the troostite nodules to grow in size if the nodular form of structure replaces the needle structure. As a matter of fact, the nodules remain the same size and the carbide which they contain tends to coalesce into small globular particles, marking not only the border outline of the nodule but also the outlines of the fan-shaped grains.

"The needle and nodular patterns are structures which result from quenching and not from tempering. The excess constituent in the case of hypo- or hyper-eutectoid steels appears to be eliminated or cleared by means of the constituent troostite. The constituent martensite (needles) appears not to be involved in this phenomenon in quenched specimens when both troostite and martensite are found to be present."

TENSION TESTING

of metals—new standard methods

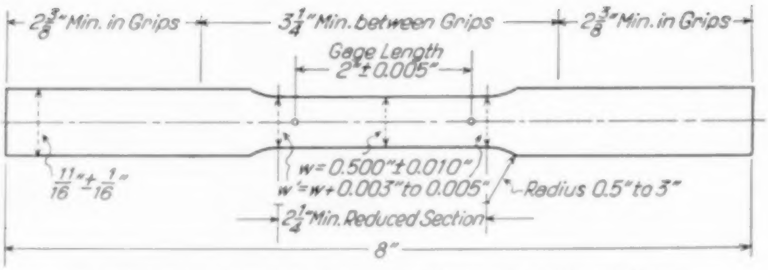
By R. L. Templin
Chairman
Section on Tension Testing
A.S.T.M.

SINCE the tension test is the mechanical test most frequently made (except the hardness test) it is well to draw attention to some changes in approved methods of making it. The methods of tension testing of metallic materials adopted as standard by the American Society for Testing Materials last year and designated as E 8 – 33, are believed to represent a real advance over similar standard methods previously in vogue and subsequently revised by that society. These new standard methods are very closely related to the work of other committees concerned with definitions of terms relating to methods of testing (contained in tentative specification E 6 – 32 T), methods for verification of testing machines (E 4 – 33 T), and methods of compression testing of metallic materials (E 9 – 33 T). All experimenters and testers would do well to study these documents.

In the development of more satisfactory methods of testing, satisfactory definitions of the terms involved are quite essential. The loose use of terms such as elastic limit, yield point, and proportional limit of elasticity, now rather prevalent, is a good example of a common source of misunderstanding or misinterpretation of the numerical values obtained from tension tests of metallic alloys.

Many of the difficulties in making tensile tests of metals, especially those supplied in the form of thin sheet, may be attributed to the type of grips used in the testing. Accordingly we find considerable attention given in the new standards to types of grips suitable for threaded end specimens, shouldered end specimens, flat sheet, round wire, tubular products, and brittle materials. Specification E 8 – 33 should be consulted for details.

Because of what has been learned about the effects of size and shape of test specimen on the mechanical properties of metals, there is a definite tendency toward more explicit specifications as regards dimensions of test pieces. Accordingly, we find much attention given to this phase of the subject in the standards, especially in the case of the standard tension test specimen for sheet metals. Preparation of tensile specimens when not properly done may introduce factors which will materially affect the test results. The new standards, therefore, have called attention to the more important conditions, met with in practice, which are to be specifically avoided.



Standard Tension Test Specimen for Sheet Metals. Machining dimensions shown below, and testing dimensions above specimen. There should be a gradual taper from ends of reduced section to middle

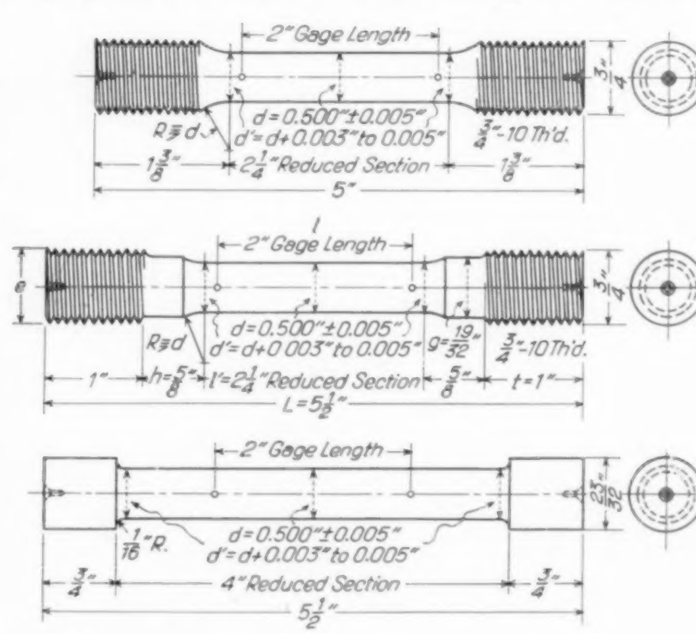
The finished tensile test piece for sheet metal is shown in the first sketch (above). The blank for the specimen should be cut in a known direction relative to the processing of the sheet, and should have a minimum width of ¾ in. if sheared or sawed from material up to ⅛ in. thick. Exact symmetry about the longitudinal axis should be the aim; small irregularities will affect the results appreciably.

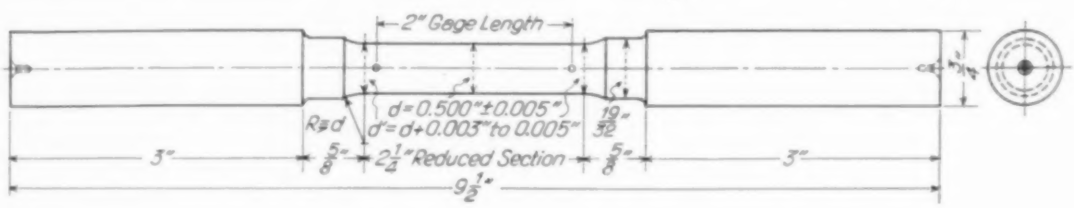
Dimensions for only one size of round tensile test specimen are given in the new standards, namely, diameter ½ in. ± 0.01 for 2¼-in. parallel section, gage length 2 in. ± 0.005, and fillet not less than ⅛ in. radius. The details of the shouldered and threaded ends of specimens are given in more complete detail, and the use of smaller specimens of proportional dimensions is permitted. Four alternative details of tensile specimens which have been found quite satisfactory in practice known to the present author and which meet the new standard requirements are shown in sketches alongside. A series of dimensions of round specimens proportional to the second from top are shown in the table at the foot of page 31. In all cases, fillets at the ends of the reduced section must not be less than the diameter of the reduced section, and the reduced section has a gradual taper from ends to middle, according to the dimensions quoted. While these smaller specimens are dimensioned with threaded ends, they can also be prepared with any of the other styles of ends shown in the drawing. In general, the largest possible size of specimen up to ½ in. should be machined from the material.

In determining the cross-sectional area of tension test specimens, emphasis is placed on the use of actual measured dimensions rather than nominal dimensions. The apparent stresses in the specimen, however, are based on the original cross-sectional area of the specimen and not on the reduced area obtaining at any given load. The maximum strength of the material, by definition, is therefore obtained by dividing the maximum load carried by the specimen, by the original cross-sectional area of the specimen.

Specimens and methods indicated in E 8 – 33 for testing metallic tubing represent a distinct improvement over previous standards. Close adherence to the details of the methods given will insure very satisfactory results, and remove many causes for arguments.

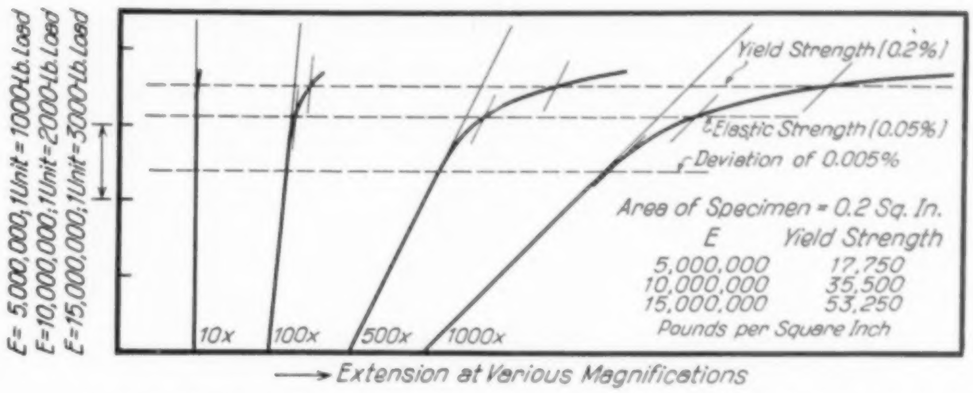
While marked progress has been made in formulating the best possible standard methods for making tensile tests of metals, certain deficiencies may yet be noted in the new specifications. The requirement governing the *speed* of testing is a conspicuous example. Few indeed are those concerned with testing metals who fail to appreciate the effects of variations in speed on the tensile properties. Within the elastic range of a metal,





Satisfactory Designs of ½-In. Tensile Test Specimens Which Conform to the Requirements of the Latest A. S. T. M. Specification E 8-33

either the rate of deformation or the rate of loading may be used as a criterion, but in the plastic range it is quite evident that only the rate of deformation will be a satisfactory basis for defining speed of testing. Very few of the testing machines in use today, however, are so equipped that the speed of testing can be controlled by the rate of plastic deformation of the tensile specimen.



Curves Showing the Effect of Magnification Factor, Applied Either to Stress or Strain, on the Apparent Accuracy of Yield Strength Constant

It is therefore desirable, if not mandatory, to omit speed requirements from standard specifications, requirements which cannot be used generally in present-day commmercial testing. A committee of the A.S.T.M. is giving much attention to the difficult problem of drafting suitable methods for defining and specifying testing speeds, and as soon as the results of their efforts are available they will undoubtedly be incorporated into the standard methods for making tensile tests of metals.

"Yield Strength"

A new section pertaining to the determination of the proportional limit, elastic limit, yield strength, yield point, and tensile strength deserves particular attention because it introduces the new term "yield strength." Yield strength is defined as "the stress at which a material exhibits a specified limiting permanent set." The term has been evolved in response to an expressed need for a stress value corresponding to the yield point so familiar in the testing of wrought iron and mild steel.

Apparently, the yield strength will serve a useful purpose in the specification and testing of metals that do not exhibit the rather unique phenomenon of undergoing, at some stress, a marked increase in strain without an appreciable increase in stress. Among the metals for which there is a need for some such new term may be listed (*a*) stainless steel, (*b*) severely cold worked, low carbon steel, (*c*) certain heat treated alloy steels, and (*d*) most of the non-ferrous metals. Detailed methods are given for the determination of the yield strength; in so doing it has been found necessary to recognize two distinct types of metals — one in which the material has a "sharp-kneed" stress-strain diagram, and the other wherein the stress-strain diagram in the region of yielding is a smooth curve of gradually changing curvature.

Much interest has been shown in the new standard "set method" for determining the yield strength of metals which do not have a "yield point." The method involves the selection and adoption of an arbitrary constant value of "set" for any given metal, a responsibility which seems to belong properly to committees responsible for formulation of proposed standards or modification of existing ones covering specific metals or metal products. A value of 0.2% has been used for many years for nonferrous metals both in this country and abroad, but so far producers and

Dimensions of Various Sized Tensile Test Specimens

Nominal Size	Dia. at Center d	Dia. at Fillet d'	Dia. of Shoulder s	Dia. at End e	Gage Length l	Reduced Section l'	Fillet + Shoulder h	Threaded Length t	Threads per In.	Overall Length L
1/2	0.500±0.005	d+0.004	19/32	3/4	2	2 1/4	5/8	1	10	5 1/2
7/16	0.438±0.004	d+0.004	1/2	5/8	1 3/4	2	5/8	7/8	11	5
3/8	0.375±0.003	d+0.003	29/64	9/16	1 1/2	1 3/4	1/2	3/4	12	4 1/4
5/16	0.313±0.002	d+0.002	25/64	1/2	1 1/4	1 1/2	1/2	5/8	13	3 3/4
1/4	0.250±0.001	d+0.002	11/32	7/16	1	1 1/4	3/8	1/2	14	3
3/16	0.188±0.001	d+0.001	9/32	3/8	3/4	1	3/8	1/2	16	2 3/4
1/8	0.125±0.001	d+0.001	3/16	1/4	1/2	3/4	5/16	3/8	20	2 1/8

consumers of ferrous metals seem reticent about agreeing to a value or values. The stress-strain curves on the top of page 31 illustrate the variations in yield strength depending on the constant used for set. They also serve to show how important it is, in selecting a value for the set constant, to take into consideration the magnification and precision of the extensometers available to the experimenter.

Before a satisfactory value for the set constant can be selected and agreed upon, it is quite necessary to have a number of both accurate and typical stress-strain diagrams from tensile tests of the particular metal being considered. The larger the value selected, the easier it is for different laboratories to check each other's results. The smaller the value agreed upon, the more satisfactory it appears to the theoretical designer, since it gives a stress value closer to the proportional limit of elasticity. Common sense would indicate such a compromise between these limits as would be practical in the commercial testing of metals.

Requirements concerning extensometers in the new standards are quite brief, merely specifying that they shall read unit deformation to 0.0001 in. Some of the older standards specified that the extensometer should be attached to the specimen at three equally spaced points; others at two points on opposite elements of the specimen. There are apparently insufficient data available to warrant these more specific requirements in the new standards. Again, it has been recognized that there are other more important requirements in good testing procedure; such as alignment of specimen, axial and uniform application of load, and accuracy of machining the specimen.

Much needs to be done in the development of better extensometers before more rigid specifications are adopted concerning them. Furthermore, some of the standard methods do not require as accurate an extensometer as others — for example, the approximate versus the more accurate set method. There are many kinds and types of extensometers now available, such as optical, mechanical, electrical, and combinations of these. It may be said that each has short-comings in its present form in spite of the many improvements that have been made.

R. L. Templin

Chief Engineer of Tests, Research Laboratories of Aluminum Co. of America, has subjected the common methods of testing metal to searching investigation and analysis, and has written and lectured extensively on these subjects

Calibration of Extensometers

As yet no requirements are given in the standards for calibration and accuracy of extensometers. These might well be considered for future inclusion in standard methods when acceptable procedures and limits become evident. Meanwhile comparative tests indicate that satisfactory results can be obtained with the available extensometers when they are used carefully and conscientiously.

So far the standard methods of tension testing, like many of the other standards of the American Society for Testing Materials, have avoided the problem of how far the mathematical reduction of test values should be carried. For example, if a test specimen having an area of 0.200 sq.in. broke under a total load of 9530 lb., should its tensile strength be recorded as 47,650 psi. or 47,700 psi.? This same problem arises in almost any experimental determination, be it mechanical, chemical, electric, or what, and it would seem reasonable to carry computations only to a point warranted by the accuracy limits specified or implied in the measurements.

In conclusion, one may point out that the standard methods adopted by the A.S.T.M. do not represent the highest type of procedure known in the testing of metals, but are an acceptable compromise between producer and consumer which will give satisfactory results under commercial production conditions. Because of the empirical nature of the details of the standard methods, it is highly important that the specific requirements indicated be rather rigorously followed if the resultant test values are to be strictly comparable.

5% CR STILL TUBES

service records are satisfactory

By E. S. Dixon
Refining Department
The Texas Company
Port Arthur, Texas

WHEN equipment for distilling oil at high pressure was first developed, carbon steel was used for tubes in heaters operating under temperature and pressure, and was satisfactory when oils with relatively low corrosion rates were processed. Even at the present time there are many locations where carbon steel is the economical metal to use, as the oils are mildly corrosive. As the art of cracking of oils developed, through use of higher temperatures and pressures, rapid corrosion became more common and severe failures in heater tubes were experienced. The first photograph on page 34 shows three such failures which occurred seven to ten years ago and represents early difficulties with carbon steel.

About 15 years ago refiners began a systematic study of various alloys to resist corrosion. Specimens of various alloys were suspended in different locations in refinery units. From this study it was learned that chromium alloys and aluminum alloys were remarkably resistant to corrosion in cracking units. Chromium alloys because of their excellent physical properties under high temperature and pressure received considerable thought, and various chromium alloys of the stainless iron type were used for pump parts, valve gates and stems, bubble caps and trays, burners, and miscellaneous refinery use.

The next step was to test these alloys for use in heater tubes.

Space does not permit a systematic account of the various experiments with alloys similar to the original cutlery analysis, the 16 to 18% chromium tubes, and alloys with 18% chromium, 8% nickel. Suffice it to say that the oil man, in his search for corrosion resisting alloys, used those then available to the industry. The first stainless steels were designed for every day use, such as in cutlery, and because they were resistant to stain and moisture corrosion (rust).

These steels were not found to be generally suitable for refinery use. However, the net result was a feeling of distinct encouragement, and in 1925 a series of tests was initiated by the oil industry to determine how little chromium could be incorporated in a steel having an analysis suitable for the manufacture of seamless steel tubing. The primary purpose was to develop a moderately priced steel which would have marked resistance to corrosion because of the chromium content, even though not *wholly* resistant.

The graph on page 35 was compiled from this series of tests. It shows a sharp decrease in corrosion rates under refinery conditions for relatively small increase in chromium content. The decrease in corrosion rates is not so marked for the higher chromium contents.

The location on this curve identified by 4 to 6% chromium was selected as being of interest. The chromium content was sufficiently high to have a corrosion restistance three to four times that of carbon steel, and it was felt that the physical properties of this steel would be more nearly similar to those of a carbon steel, rather than to a stainless steel.

In November, 1927, the first installation of 4 to 6% chromium heater tubes was made. These tubes were in service for two years; their corrosion rate was low and they did not fail by bursting wide open without bulging. The type of failures experienced was similar to those with carbon steel tubes.

Ample experience shows that 4 to 6% chromium steel is a corrosion resisting alloy where the corrosive medium contains hydrogen sulphide or any sulphides which react with iron, steel, brass or monel, giving iron sulphide, copper sulphide or nickel sulphide as the products of corrosion.

While the principal refinery use for the 4 to 6% chromium steels has been in pressure still equipment, this steel should not be used generally, or in a new location until a preliminary study of corrosion conditions has been made. A refinery experiencing corrosion in pressure stills or other equipment should place specimens of various metals in stills, towers, lines and other equipment. The procedure for testing should be that developed by American Petroleum Institute's Committee on Corrosion. The test bars should include among others carbon steel, 4 to 6% chromium steels and 18-8; a relative value with respect to corrosion resisting properties will readily be determined. If the 4 to 6% chromium steel shows no marked corrosion resisting properties as compared to carbon steel, then it should not be considered. If it shows a value three to four times that of carbon steel, it then becomes an economic problem as to whether it pays to install this relatively expensive chromium steel and have it last three to four times as long as the cheaper carbon steel.

For example, if carbon steel tubes are removed from a unit every six months and 4 to 6% chromium steel lasts four times as long, the economy is certainly justified. If, on the other hand, carbon steel lasts three years or more, then the alloy steel is probably not justified, for it is possible that equipment is obsolete before 12 years have elapsed.

At temperatures 800° F. to 1200°F. the creep and short time ultimate strength of the 4 to 6% chromium steels are greater than for carbon steel. At these temperatures a refiner has the option of using heater tubes and outside lines of thinner wall thickness than if they were made of carbon steel.

Three Carbon Steel Tubes Which Failed in Service i Pressure Still. Observe the heavy scale, showing the temperature of the tube wall, and which is responsibl thinning the metal in the center one to cardboard thick

At temperatures between 1200° F. to 1300° F. there is but little advantage to be gained in using 4 to 6% chromium steels for long time service, as their creep strength is very little above that of carbon steel (unless, perhaps, tungsten or molybdenum is added to the analysis). However, at these temperatures the short time ultimate strength of the 4 to 6% chromium steels is approximately 50% higher than that of carbon steel, which results in a greater safety under adverse conditions. Through their use the number of failures at these temperatures has been reduced.

Specifications for Purchasing

When purchasing tubes of 4 to 6% chromium steel, Specification No. 200, adopted by Association of American Steel Manufacturers' Technical Committee, is satisfactory. This specification can be added to or corrected as the customer choses. Specifications for castings are being included in tentative specifications for alloy steel castings for valves, flanges and fittings for temperatures not exceeding 1100° F. now being compiled by Sub-Committee XXII of Committee A-1, American Society for Testing Materials.

The use of 4 to 6% chromium steel tubes requires certain precautions in installation:

(1) The metal must be soft enough to expand when rolling into headers. The power required to roll in these tubes is greater than to roll in carbon steel tubes. While not absolutely necessary, it is advisable to roll chromium steel tubes into headers or junction boxes with the steel heated above 70° F. For 4 to 6% chromium steel, with or without molybdenum, a Brinell test should show a hardness number not to exceed 163 for material ordered with a maximum carbon content of 0.15%, and Brinell 170 maximum for material ordered with a maximum carbon content of 0.20%.

(2) For fabricating tubing bends in pipe bending shops, 4 to 6% chromium tubes can be bent hot or cold, depending on the diameter of the pipe and radius of the bend. Bends made cold of 4½-in. tubing have been in service over four years. When bends are fabricated hot, care should be taken to see that temperature when bending is in excess of 1500° F.; due care is also to be exercised to avoid sudden chilling

nd Tests on Welded Specimens Cut From Tubes Made of 4 to 6% romium, 0.5% Molybdenum Steel. Tubes were from two steel kers. Tension tests usually fail in the joint, well necked down

from a cold blast of air or water quench. Finally, careful and correct heat treatment of the finished hot bend is necessary. It is not necessary to heat treat cold bends. The fabrication of alloy steel tubes into bends thus requires a technique different than that used in carbon steel.

(3) The air hardening properties of this metal must always be remembered, particularly when hooking up equipment in the field. Any heating which causes air hardening must be followed by the proper heat treatment whether in the shop or in the field.

Welding Practice

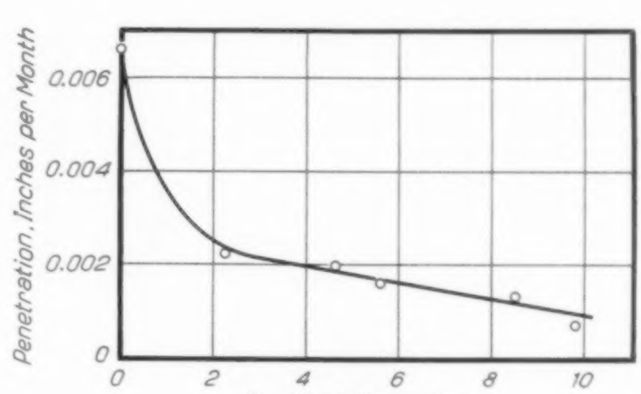
Heretofore it has been the general contention that it would be practically impossible to weld, in a safe and reliable manner, those chromium steels which possess pronounced air hardening and low impact properties when air cooled from the high temperatures that accompany arc welding operations. However, the technique of electric welding of 4 to 6% chromium alloy steel has been satisfactorily developed both in the shop and field by a large oil refinery in the Southwest; welding has therefore been adopted as a method of making joints and connections in fabricating and repairing 4 to 6% chromium steel parts in cracking still equipment.

Chromium steels of this type are being welded with a heavily coated electrode containing 4 to 6% chromium, 0.5% molybdenum, and a maximum carbon content of 0.15%. These electrodes are sold by several nationally known manufacturers of welding equipment.

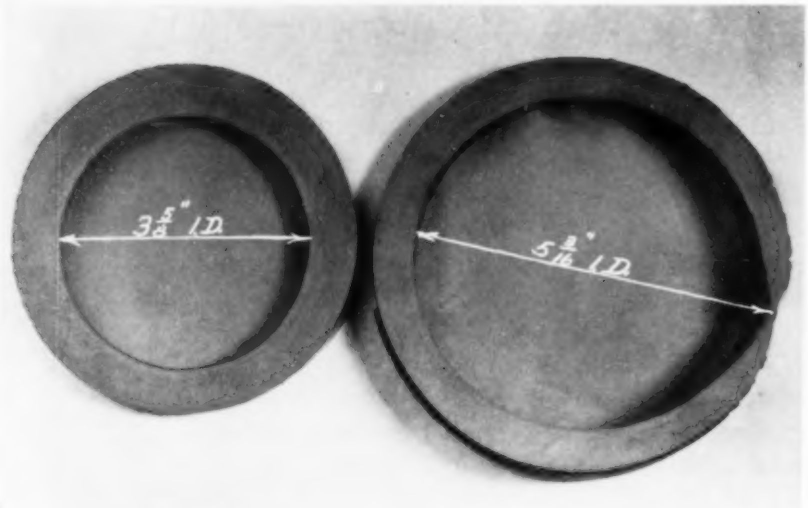
Previous to all welding operations, the members are assembled in place and the joining lips of the plate are heated between 500° and 600° F.; they are then tacked together with the above-mentioned electrode. Welding is done with reverse polarity (that is, electrode positive), and each layer of weld metal is deposited in the same manner as when using covered electrodes of plain carbon steel. Previous to the deposition of each layer of metal the adjoining plate material is heated to 500 to 600° F., and should not at any time before completion of the weld be allowed to cool below 300° F. At 300° F. or above, air hardened 4 to 6% chromium steels possess sufficient toughness and ductility to prevent the deposited weld metal from cracking due to contraction stresses.

The simplest form of welding is in a flat downward position, but a skilled welder can satisfactorily do vertical and overhead welding.

Immediately after completion the weld should be annealed at 1600° F. and slowly cooled, in order to eliminate the undesirable characteristics which air hardened chromium steel possesses (this includes both field and shop welds).



Relation of Corrosion Rate and Chromium Content of Steels When Handling Certain Corrosive Crudes at High Temperature and Pressure



Original Tube at Left Expanded by Overheat and Pressure to Size at Right Before it Split at Arrow Mark

The photograph on page 35 shows the ductility of the weld metal. (All of these examples were taken from specimens of steel from two pipe makers, welded and annealed under field conditions). Metallurgical examination of field welded metal reveals that less than 0.25% chromium is lost during the welding operation, and that the structure of the final annealed weld and adjacent plate material has a fine and uniform appearance — even superior to the parent plate.

Corrosion tests on this type of welded joints have consistently shown, in actual service, that the deposited weld metal is equal to the parent plate in resisting deterioration. Hot oil pump discharge lines with field welded and annealed joints operating under 500 psi. pressure at 800° F. for one year have revealed both a very reliable, practical and dependable type of construction for the refinery industry.

The life of 4 to 6% chromium tubes in pressure still service is from four to eight times the life of carbon steel when appreciable corrosion is experienced, and corrosion is uniform rather than of the pitting type. If this alloy steel is not sufficiently superior to carbon steel with respect to corrosion, then it should not be installed.

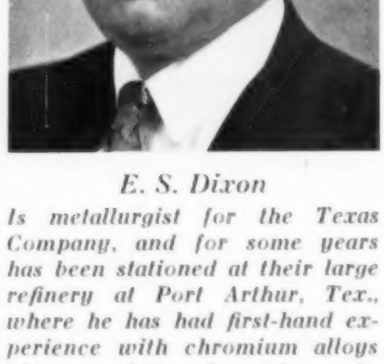
Tubes made of 4 to 6% chromium steel when operating hot (above 300° F.) are ductile and tough. The impact value for this steel when hot is excellent. Although the creep strength at 1300° F. is approximately that of carbon steel, its short time strength at 1300° F. is better than carbon steel, therefore, tubes operating at a red heat — as do many tubes — swell gradually rather than bursting wide open, giving operators due warning.

Hot Tubes Are Ductile

This ability to swell gradually is an important feature for this type steel, and an installation of heater tubes in ten batteries of pressure stills has operated over four years, with no sudden failures which can be attributed to the quality of metal.

The view alongside shows the tendency of this metal to swell gradually under temperature and pressure. The cross-section at the left is the original tube; that on the right was cut through the tube at the swelled portion. The diameter has increased $1\frac{9}{16}$ in., but the tube did not burst wide open. In another failure, where a tube split for a short distance, the internal diameter had increased from 4 in. to $4\frac{3}{8}$ in. by creep in two years' service, yet the wall thickness was the same as specified in the original tube within the limits of accuracy of our measurements. The average loss in metal wall thickness on the 4 to 6% chromium tubes in these ten heaters mentioned above has been less than 1/16 in. after over four years in operation.

Although tubes of this alloy are strong, ductile, and tough when heated, a tendency to be brittle when cold developed after two years of operation. This trait is particularly noticeable during the cold months, when batteries are down for cleaning and the tubes are cleaned with mechanical knockers. This subject has been discussed in a paper presented by Wilten and Dixon at the June, 1934, meeting of the American Society for Testing Materials entitled "Aging Embrittlement of 4 to 6% Chromium Steel." The precautions to be taken when using chromium steel tubes containing no molybdenum are to clean the tubes when the unit first comes off the line. or before the tubes have cooled to a minimum metal temperature of approximately 300° F. through the entire length. If the tubes have cooled below the minimum metal temperature, they should be reheated before starting to clean.



E. S. Dixon

Is metallurgist for the Texas Company, and for some years has been stationed at their large refinery at Port Arthur, Tex., where he has had first-hand experience with chromium alloys of a variety of analyses in severe oil refinery services

PITTING OF 18-8

in navy use

An Editorial

This article is not to be construed as official or reflecting the views of the Navy Department

RUMORS of serious failures of corrosion resisting steel in warships of the U. S. Navy have been circulating for several months, and finally reached publication on the first page of the New York *Times* and an Associated Press dispatch saying the Navy had decided to eliminate such steel from vessels now under construction. This bad news (quite inaccurate) has traveled fast, and, although quickly denied by responsible naval officers, has disturbed many consumers of the corrosion resisting steels, and raised some doubts as to the utility of these alloys for severe service. The facts are worthy of record:

The Bureau of Construction and Repair, U. S. Navy, has been interested in corrosion resisting steels ever since their commercial production. They offered opportunities for weight saving and permanence when replacing galvanized steel or wrought iron; the latter either had to be used in extra heavy section to provide for corrosion losses or replaced before the ship became obsolete. Weight saved on the top sides increases the stability of the ship and permits an equal increase in power plant or armament. Consequently the Navy has put an important tonnage of strip and sheet analyzing 18% chromium, 8% nickel (the so-called 18-8) into deck houses, floors, hatch covers, and a variety of other structures exposed to atmospheric corrosion in port and to dashing spray or water in a seaway. In these places the metal has served excellently, and the Navy has no intention of avoiding such uses in the future. The same may also be said of some other applications of corrosion resistant steel where the metal is attached to the hull so it is submerged almost continuously, such as rods and arms for operating diving fins on submarines, and stranded wire cables for mooring.

These satisfactory results encouraged the naval constructors to put corrosion resisting steel into two applications in which unfortunately it did not stand up — namely, gasoline stowage tanks and fire lines. Let us examine the circumstances surrounding such failures.

Salt water is pumped into the bottom of the tanks so the gasoline can be drawn off under hydraulic pressure at all times; consequently the stowage tanks contain variable quantities of gasoline, doped with tetra-ethyl lead and ethylene dibromide, and sea water more or less fouled with marine organisms or diluted sewage. Tanks on the first aircraft carriers had been made of galvanized steel plate, welded, with welds tinned — a reasonably satisfactory construction. On the newer ships the tanks were to be built into the hull in quite inaccessible locations, and the use of 18-8 promised absolute immunity from leakage (most dangerous in confined spaces aboard ship!) for the entire life of the hull.

The second unsatisfactory experience was with fire lines of thin-walled seamless tubing, installed on the latest 10,000-ton cruisers. In older ships galvanized steel or iron pipe has been used, much heavier in wall thickness and of less life than the hull. It was anticipated that the 18-8 would resist sea water perfectly, and not only save considerable weight, but also the cost of expensive replacements.

In both situations the stainless steel failed by pitting in as short a time as six months! These two are the applications which have given all the trouble, which are being removed from existing ships, and which will not be resumed until the cause is definitely known and cured. It would be a dis-service to corrosion resisting steel to gloss over the facts, and allow other users to stumble into similar troubles. A multitude of laboratory

salt spray tests and extensive naval experience prove that commercial 18-8 is totally resistant to common salt (sodium chloride), sea salt and sea water when moving vigorously and aerated, or to seashore and marine atmospheres. Trouble by pitting arises from more or less stagnant sea or harbor water, and there is not the least cause for worry about a multitude of applications in dozens of industries where chloride ions, stagnant solutions, and foul deposits are not encountered or not permitted.

Very serious study has been given to these failures, both by naval personnel and various metallurgists. It would be well to list some of the findings to date.

The first gasoline tanks were of welded plate, and the heat treatment subsequent to fabrication was improperly done. Damaging pits occurred in locations where the metal had not been quenched rapidly enough in final heat treatment, a condition which makes 18-8 susceptible to intergranular corrosion, as is well known. To avoid this condition on later tanks they were made of metal higher in alloying elements (approaching 19% chromium, 9% nickel), lower in carbon content, and unusually clear of solid non-metallic inclusions — all matters which are believed to increase the stability of the alloy — yet serious pitting occurred in a few months! Location of these pits could not be correlated with welds, bends, or position of plate. Large areas were unaffected. Some pits were so small or tightly closed as to elude careful inspection and were located only by "weeping" of gasoline outside. The under-surface cavities, when cut into, are of various shapes, and contain entrapped moisture so tenaciously that bubbles of corrosion products are exuded even after months in dry, warm storage. Others are open at the top, as big as oyster shells.

Pits in the fire-line piping were also independent of position, proximity to welds, pipe ends, or contact with dissimilar metals. Cast 18-8 valve fittings were penetrated as rapidly as the pipe walls only 25% as thick, leaking through spongy areas in bodies and flanges.

The conclusion which may be reached from the data is that general attack by chemical reaction with sea water is not a factor in these two services; neither is corrosion by oxidation, by intergranular attack, nor by electrolysis set up by contact with dissimilar metals. Some experimenters blame the trouble on (a) "contact corrosion" under non-metallic substances (either scale or inclusions), or under solid particles brought in by the water, or (b) corrosion by "oxygen concentration cells" existing in porosities and pits or caused by lodgment of organisms or even dead organic matter which has a reducing or deoxidizing nature.

If these conclusions are correct, then a successful 18-8 for these two services must be free of non-metallic inclusions with polished surfaces, and the sea water must be filtered even of microscopic organisms and particles of metal from pumps or valves. Obviously, none of these requirements can now be met, either by steel maker, fabricator or naval engineer, and the decision to abandon 18-8 for gasoline tanks and fire lines until more accurate information is available is not to be criticised. On the other hand, investigation may show that the situation is not nearly as hopeless as it appears to the theorist.

It is noteworthy that the conditions for successful naval service differ from the unsuccessful ones in that the sea water in the first case is freely circulating and well aerated, whereas in the latter it is relatively stagnant. Idle boats in lake waters also pit severely, whereas busy boats have no such troubles with hull plates!

Extensive experimentation by research laboratories of at least two steel producers indicates that attached particles of matter, either organic or inorganic, do not start a pit, even when using harbor water as the corrodent, and particles of muck taken from the damaged pipe and tanks as accelerators. On the other hand, fairly rapid pitting can be induced in 18-8 by special solutions ("pitting solutions," they may be called) such as ferric chloride and sodium hypochlorite, and by certain solids, such as graphite and rubber.

While there is no warrant to draw a close parallel between corrosion in stagnant sea water and in "pitting solutions," some results of experiments in the latter may be informative: The evidence points to irregularities of some sort at the surface as the locus of the pit, where the normal protective coat of oxide is broken and prevented from reforming and attaching itself. Since steels with a low inclusion count pit no less freely than quite dirty ones, it is doubtful that *visible* inclusions are the culprits. Another surface irregularity may be a minor variation in the chemical composition of the iron-chromium-nickel solid solution, and this may be the locus of the trouble.

Some other interesting observations are that a sheet, known to be susceptible to pitting, is almost immune if highly buffed and polished. On the other hand, shearing or sawing out the sam-

ple seems to increase the number of pits growing in from the edge, so cold work of this sort has some accelerating action!

Assuming that variation in chemical composition or presence of oxide may locate the surface defect and be the first cause of a pit, some surface treatment can likely be devised which will remove these irregularities before it gets into service. But whether pitting once started can be stopped will be questioned by a believer in corrosion by oxygen concentration cells. This type of corrosion may start immediately wherever there are porosities of small cross-sectional area in proportion to their depth. Under such circumstances, the electrolyte in the bottom of the hole becomes poorer in oxygen than at the entrance, the oxygen-poor area is anodic to the other, and an electrolytic cell is formed. The products of corrosion (iron, chromium, and nickel ions) are carried to the cathode, that is, to the entrance of the pit, where they oxidize; even if they deposit there, they are unable to protect metal at the bottom of the pit from further attack, with the result that corrosion continues until the metal is perforated.

These considerations lead to the thought that the pitting corrosion may best be avoided by an alloy of considerably different analysis from 18-8 — one that is better capable of resisting attack by an oxygen concentration cell. The Bureau of Construction and Repair, U.S. Navy, has therefore considered the desirability of selecting individual ships in each of which will be installed a complete system of pipe of material which offers definite promise of being free from the pitting type of corrosion in sea water. Preliminary investigations indicate five such materials: *(a)* 18-8 with 3% molybdenum; *(b)* 18-8 with 5% manganese and 1% copper; *(c)* monel metal; *(d)* 70% copper, 30% nickel alloy; *(e)* rubber-lined steel. Results of such trial installations will be awaited with the greatest interest.

* * *

While the unexpected failures of 18-8 in two classes of naval service are extremely regrettable, there is no need for consternation among other users. It is not the first misapplication made with a new material — even the corrosion resisting steels have successfully recovered the ground lost after a failure in a service for which they have been mistakenly recommended when another analysis or another alloy of different nature was far better fitted.

One needs only to recollect the failure of 18% chromium-iron tubes in petroleum refinery service, embrittled by stay at high temperature. Adding 8% nickel to the analysis corrected the trouble. Then there were serious troubles with welded 18-8, corroded alongside the joint, until the proper composition, stabilizing additions, and heat treatment were discovered. Chromium-iron rivets driven in nitric acid equipment would break spontaneously until it was found that temperatures in manufacture and in driving must be strictly limited to 1400° F. Unsatisfactory experiences with 18-8 in both the woolen textile industry and the paper and pulp industry have been cured by adding 3% molybdenum to the alloy. Mirror-finished press plates of 18-8, widely used in making laminated paper products, were found to roughen quickly because of the high coefficient of thermal expansion, and the trouble was cured by a lower cost high chromium alloy having a much lower rate of expansion. Pitting of 18-8 in contact with calcium chloride refrigerants has been prevented by the use of low carbon metal and neutralizing the solution by simply immersing a bag of lime in the circulating system. Even in so simple an application as architectural trim, 18-8 will rust and pit if building filth attaches itself — but in the most severe case the original color can be readily restored by washing with Bon Ami, and rusting and pitting do not re-occur on the finished structure.

In every one of these misapplications — and more might be cited — stainless steel has probably received a black eye and temporarily lost ground. Most of them have come and gone without handicap of false reports in newspapers. However, technologists, like reporters, learn more from failures than from successes, and in all these instances it has been possible to produce a steel which overcame the difficulties of the previous type, or to make some minor change in the condition of application which cured the trouble.

While the cause and cure of pitting in stagnant sea water has not yet been discovered, the search is vigorous enough to warrant success. We know enough about it already that any intelligent user of stainless steel can appraise the conditions which exist in his service, and determine whether there is any cause for worry. If chloride solutions are handled in high chromium steels they should be kept neutral, entirely free from ferric chloride, in continuous circulation, and free from organic or inorganic solids. Periodic cleaning of the equipment is also quite desirable. Precautions such as these have been in use for years in innumerable water piping systems where an intelligent effort to mitigate corrosion has been made.

John A. Mathews

1872
1935

JOHN ALEXANDER MATHEWS died of a heart attack on January 11, 1935, at his home in Scarsdale, N. Y. He was since 1921 honorary member of American Society for Metals, and a metallurgist of world-wide fame.

For over 30 years he was among the intellectual leaders of the American steel industry. Amongst his notable achievements were the use of the electric furnace in making high quality steel, the American production of magnet steels, the improvement of high speed steel by the addition of vanadium, the development of various vanadium steels, and the improvement of heat resisting austenitic steels.

Born at Washington, Pa., May 20, 1872, he graduated at Washington and Jefferson College in 1893 and took his Ph.D. at Columbia University in 1898. He was given the Barnard Fellowship and went to Royal School of Mines, London, where he studied metallography under Sir William Roberts-Austen. Returning to Columbia in 1901,

he worked in Professor Howe's laboratory on a series of alloy steels, having been awarded one of the first Carnegie Scholarships for that purpose by the Iron & Steel Institute of Great Britain, and for which work he received the first Carnegie Gold Medal. Finishing this work, he went to the Sanderson Brothers Steel Co., Syracuse, as metallurgist in charge of experimental work and soon became assistant manager.

He married Florence Hosmer King in 1903. She, together with a daughter and a son, survive him.

When Doctor Mathews went to Halcomb Steel Co. in 1908 as operating manager, he found the first Heroult electric furnace erected in this country. It was cold, having been considered a failure, but the new manager encouraged his staff to try again, and soon the furnace was establishing a new standard of quality in alloy and tool steels.

His interest in steels for permanent magnets dates back to the days at the Sanderson works. At that time nearly all such material was imported. Five years later we were practically self-sufficient, as far as tungsten and chromium magnet steels were concerned. When, during the War, tungsten was commandeered for other purposes, he was able to devise a satisfactory substitute. He was constant in his belief that the magnetic properties of carbon and alloy steels were of use in routine testing, and that they could eventually be correlated with the ultimate structure and mechanical properties. Numberless anomalies in these relationships were cleared up by Dr. Mathews' brilliant hypotheses (contained in his Henry Marion Howe memorial lecture, 1925) that austenite co-exists with martensite in hardened steels and that more austenite is retained in certain alloy steels after quenching in oil than in water—hypotheses which have been amply confirmed by later investigators.

When Dr. Mathews first turned his attention to vanadium as an alloying element, he found that the entire American stock consisted of 30 lb. of contained vanadium in ferro, quoted at $72 a pound! Nevertheless he tried its effect on all the tool steels then manufactured by his firm, and discovered that 1% vanadium tripled the cutting efficiency of the best high speed steels then on the market. This was the first fundamental improvement to the Taylor-White steels. He also introduced vanadium into the nickel, chromium, and nickel-chromium alloy steels, and furnished samples to the late Henry Souther, who was then metallurgist for the Licensed Automobile Manufacturers Association, substantiating his claims for excellence with impact values—then seldom used.

In 1920 he was elected president of Crucible Steel Co. of America, a post he held during the difficult years between 1920 and 1923. During that time the executive staffs were thoroughly reorganized. That task completed—which taxed his ability and his humanity to the utmost—he returned to his first-love as director of research and vice-president of the corporation, a position he held at his death.

The development and perfection of the heat and corrosion resisting steels has occupied a good portion of the time of Dr. Mathews' research staffs in recent years, and a series of notable technical contributions have been the result.

Dr. Mathews took his civic duties seriously. He was a clear, lucid writer in his chosen field and published about 100 papers. He was in great demand as a speaker at chapter meetings. The number of his public, philanthropic, and technological activities is too long to quote—it would only serve to prove his versatility and his devotion to his country, his industry and his fellow man.

How easy it is to tell what a man has done, how difficult to put in words what he was! To those who knew him and worked with him, that is not necessary, for his kindly personality and the charm of his company endeared him to all. His friends everywhere will miss his optimistic smile, because he was never downhearted about business, work or research. He knew that things would turn out splendidly for those who strove for an end. Most especially those who worked in his laboratories or in the plants will feel the loss of a sympathetic leader, a patient teacher, a reliable guide and a real friend. He was a kindly gentleman.

William Campbell.

CORRESPONDENCE

and notes from abroad

Evaluation of Inhomogeneities in Solid Solutions

PARIS, FRANCE — Differences in chemical composition of the solid solution alloys arise from three principal circumstances, *(a)* dendritic segregation during solidification, *(b)* allotropic transformations in the solid state, and *(c)* precipitation or segregation of fine particles. Study of such inequalities is most important; many annealing operations are encountered whose principal aim is to restore the most uniform structure possible.

It is interesting to consider whether the irregularities in concentration on any metallic section can be plotted in the same way a topographic surveyor maps the irregularities and surface features of a given terrain. He draws a series of sinuous lines or "contours," each of which locates all points at a certain elevation above sea level. Peaks are surrounded by closed curves; the contours reach up into valleys a lesser distance as the elevation is lower.

Such a "topographic map" of a metallic surface would be drawn with "iso-chemical" contours; a given difference in actual content of the element under investigation would represent the "contour interval" ΔZ; if the change in chemical composition were very sharp these iso-chemical lines would be close together, that is, their horizontal spacing ΔX on the map would be small, and *vice versa.*

While ΔX and ΔZ depend on common antecedents, they are independent functions, and have different effects. Thus, intercrystalline corrosion depends on ΔZ, whereas the proper annealing program depends on the concentration gradient $\Delta Z \div \Delta X$. Measurement of these two values is difficult and delicate.

Of course a general idea of the steepness of the gradients (ΔX) may be had by micrographic or macrographic examination of an etched or cold worked specimen, but the data so secured are but qualitative. To determine ΔZ we may study the electrical, magnetic or mechanical properties, either (*a*) by a survey, point by point, when such is possible, else *(b)* by studying the variations in the test results as a function of the test specimen, or *(c)* by noting the variations of a given property after longer and longer anneals, causing more and more diffusion, a widening of ΔX and eliminating many iso-chemical contours at high peaks and deep valleys.

Unfortunately, many of the metallic properties determined by the research investigator are the result of an integrated effect of all internal variations, and not the maximum difference in chemical composition Z. About the only way this value can be determined is by the position and amplitude of the Curie point, and this, unfortunately, may be used only on ferro-magnetic metals and alloys.

Of course, the ferro-magnetic alloys are very important, and among them are the corrosion re-

sisting alloys of iron, nickel and chromium. In such alloys the precipitation of fine carbides or other compounds has the greatest influence on their chemical resistance and their mechanical properties (especially impact toughness). A quantitative study of these alloys made along the lines indicated above has convinced the writer that variation in chemical composition of the solid solution is at least as important as the precipitation of fine carbides and other particles of a separate phase, in influencing hardening and intergranular corrosion.

After all, it is to such differences in concentration of elements in solid solution that may be imputed the hardening of the aluminum-copper alloys which occurs prior to the precipitation of a separate phase. Similar phenomena may be responsible for many puzzling actions in metallic alloys, now unexplained.

ALBERT PORTEVIN

Alloy Steel Axles for Locomotives

TURIN, ITALY — European railroads are increasing the speed and weight of trains for the same reasons the American railroads have acted upon. This, in turn, has required a re-appraisal of certain essential locomotive parts, to insure the maximum safety under greatly increased loads. Frequently this study was extended to the early steps of manufacturing, and even into the primary steel making processes.

A typical example is supplied by locomotive axles. These, on European engines, are crank axles, for we usually mount steam cylinders close together so the connecting rods are inside the wheels, rather than outside, as on American locomotives.

Until a few years ago the standards of the principal European railway companies generally specified three different qualities of crank-axle steel ("ordinary," "superior" and "special") to be used for locomotives of corresponding weight and power. These specifications were usually based on the physical properties of the metal, and very seldom mentioned a required composition (except for sulphur and phosphorus), or a manufacturing process. An exception to this is that some French, German and Italian companies specified nickel steel for the "special" quality, the nickel content being generally in the range 3% to 5%. The reason of this chemical specification has not been recorded.

When the requirements had to be materially increased to meet the new conditions of service, the efficiency of the heat treatment of the axles (either carbon or nickel steel) became of paramount importance. At the same time, the dimensions of the pieces to be heat treated were greatly increased — especially on account of the general adoption of one-piece axles in place of compound axles. It therefore became necessary to use steels capable of receiving a deep heat treatment, and chromium-nickel and chromium-nickel-molybdenum steels were introduced.

However, other serious troubles were experienced with these alloy steels for two main reasons. First of all, the tendency of these steels to form large primary crystals when cast in ingots large enough for the one-piece axles, often led to local defects, caused by the great extent of the processes of liquation — that is, the intense accumulation of impurities at the boundaries of the primary crystals. These defects act as "primers" of cracks, and had the well known harmful effect on the endurance of the axles. In the second place, the peculiar tendency of the above mentioned steels to retain non-metallic inclusions increased materially the number of rejects after finishing, on account of "lines" on machined journal surfaces.

After many troubles accountable to these peculiarities, practically all railway companies introduced in their specifications very severe clauses requiring the steel maker to guarantee a minimum life for locomotive axles. Some of the French companies, in an effort to avoid the harmful effects of impurities, specified acid open hearth steel for "special" axle steel.

Though these difficulties are now minimized by improvements in the melting, casting and treating processes, there is a strong tendency among European manufacturers and railway companies to abandon chromium-nickel steels for locomotive axles, and to adopt chromium-molybdenum steels. The results obtained with the latter have been excellent in every respect, including high resistance of the journals to wear.

FEDERICO GIOLITTI

Rapid Nitriding of Steel

MOSCOW, U.S.S.R. — We have been much interested in the nitriding process, since it produces surfaces of unique properties. Consequently an effort has been made to remove its worst shortcoming, namely, the long time required. Successful work *(Cont. on page 52)*

TOUGH MACHINE PARTS

copper brazed in electric furnace

By USE of the modern process of brazing with copper in an electric furnace with controlled atmosphere, the Union Special Machine Co. of Chicago, manufacturers of sewing machines for the needle trades, has been able to make high-quality parts having greater strength and longer life, though costing less, than those made by former methods of fabricating, such as riveting, pinning, torch brazing, and machining from solid bar stock.

Because of the high speeds at which these sewing machines run, the parts are subjected to very severe alternating stresses. Speeds of 4000 and 4500 r.p.m. (that is, 4000 and 4500 stitches per min.) are not uncommon! In fact, one of the machines recently introduced is the fastest known; it makes 6000 stitches per min., or 100 per sec. Under such severe conditions riveted, pinned, and torch-brazed parts would work loose in service, mainly because of the imposed vibrations. However, the new process has overcome this difficulty and is producing assemblies which are strong and durable and are highly resistant to vibration and alternating stresses.

The illustration above shows some of the assemblies which are now being brazed in an electric furnace by the Union Special Machine Co. *A* is a tension release, formerly made by riveting four steel bars into a long, flat stamping. Although this was an inexpensive method of fabricating the assembly, continual vibration caused the riveted joints to work loose. Such occurrences and the shutdown for replacement resulted in loss of time and money. This difficulty and expense has been entirely overcome since the new brazing process has been used to fabricate these assemblies, because of the high strength it imparts to the joints.

The process may conveniently be described by describing the method of preparing this tension release *A* for electric furnace brazing. Other more simple, and even much more complicated parts, would be treated similarly.

The bars are riveted to the stamping, as was previously done, but merely in order to hold them firmly in their proper positions during fabrication. Then a paste containing copper powder is daubed about the joints, and a number of the assemblies are placed on a light-weight alloy tray. This completes the preliminaries.

The tray is then placed in the box-type electric furnace with controlled atmosphere shown overleaf, and is allowed to come to temperature (2100° F.). As the temperature of the cold assemblies increases, hydrogen and carbon monoxide in the controlled atmosphere react with any scale, rust, grease, or paint vehicle which may be present on the surface of the steel, and by the time the melting point of the copper powder is reached (1975° F.) an absolutely clean, scale-free surface is ready. In this manner the reducing atmosphere takes the place of the flux ordinarily used in a welding, brazing, or soldering operation, only far more efficiently.

At 2100° F. the copper becomes very fluid, flows into the joints by the aid of capillary attraction, and alloys with the surface of the steel. The tray is then pushed into an adjoining water-jacketed cooling chamber in which a controlled atmosphere is also maintained and in which the alloys solidify and form a strong bond. This bond is much stronger than pure copper; tests show that it frequently approaches the strength of steel. When the trays are removed from the cooling chamber, the parts have clear, bright surfaces and are ready for installation into the sewing machines without any further cleaning or pickling operations (which fact frequently realizes additional savings).

Bevel gears, identified as parts *B*, *G*, *H*, and *I*, are made for the various drives in the sewing machines. Formerly they were cut from solid bar stock with the production of a large percentage of turnings, but now the small gears are made of short lengths of thick-walled seamless tubing, pressed onto smaller tube for the hollow shafts, and electric furnace brazed. By eliminating much of the time and material consumed in the machining operations, the new method of fabricating obviously effects a substantial saving.

Other assemblies which were formerly machined from solid bar stock are the main drive shafts, parts *C*, *D*, *E*, and *F*. Formerly, when these shafts had been turned down, the flanges at the ends were milled to the proper shape. Now, the shafts and cams are made of the most economical stock and simply copper-brazed in the electric furnace. By eliminating certain machine operations this saves considerable money and, in addition, speeds up production. The assembly is interesting:

The end of the shaft is turned down for a short distance and is pressed into a tight hole in the flange or cam. A ring of copper wire is then slipped over the shaft, up to the joint. Despite the fact that the two parts have a pressed fit, the molten copper penetrates completely. *F* and *M* are cross-sections of these assemblies, after brazing. The pieces have been so completely united that the copper-brazed joints, after the sections have been cut and polished, are barely visible to the naked eye, and cannot be photographed except after polishing and etching.

L, *P*, and *J* are parts known as "pressure feet." The stud-like bearings, used for mounting the pressure feet on the machines, were formerly brazed in position by hand with a torch. This method, besides being tedious, did not give uniform results; rejections were numerous. Cleaning after torch brazing was also a source of expense, and further losses in time and money resulted from failures in service. Now, since these assemblies have been fabricated by the modern process, they are uniformly strong, clean, and bright; their life has been materially increased and notable savings have been made in both time and money through complete elimination of failures in service.

Another assembly brazed in the electric furnace is the feed link,

H. E. Scarbrough

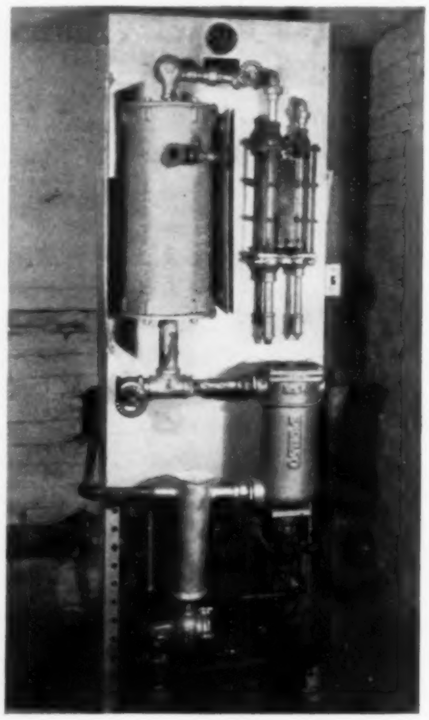
Author of this article is a specialist in industrial heating for General Electric Co., and a member of American Society for Metals, Chicago Chapter. He has been with G.E. Co. ever since his graduation from Georgia School of Technology

part *N*, which consists of a small forging with a pin pressed and brazed into one end. In service, these pins now stay in place indefinitely.

The pressure bar, part *K*, is interesting in that it was given a severe test before being photographed. The bar was clamped in a vise, and the pin, which had been electric furnace brazed into the end, was twisted through an angle of about 90°. All the twist occurred in the pin — no noticeable effect could be observed at the joint.

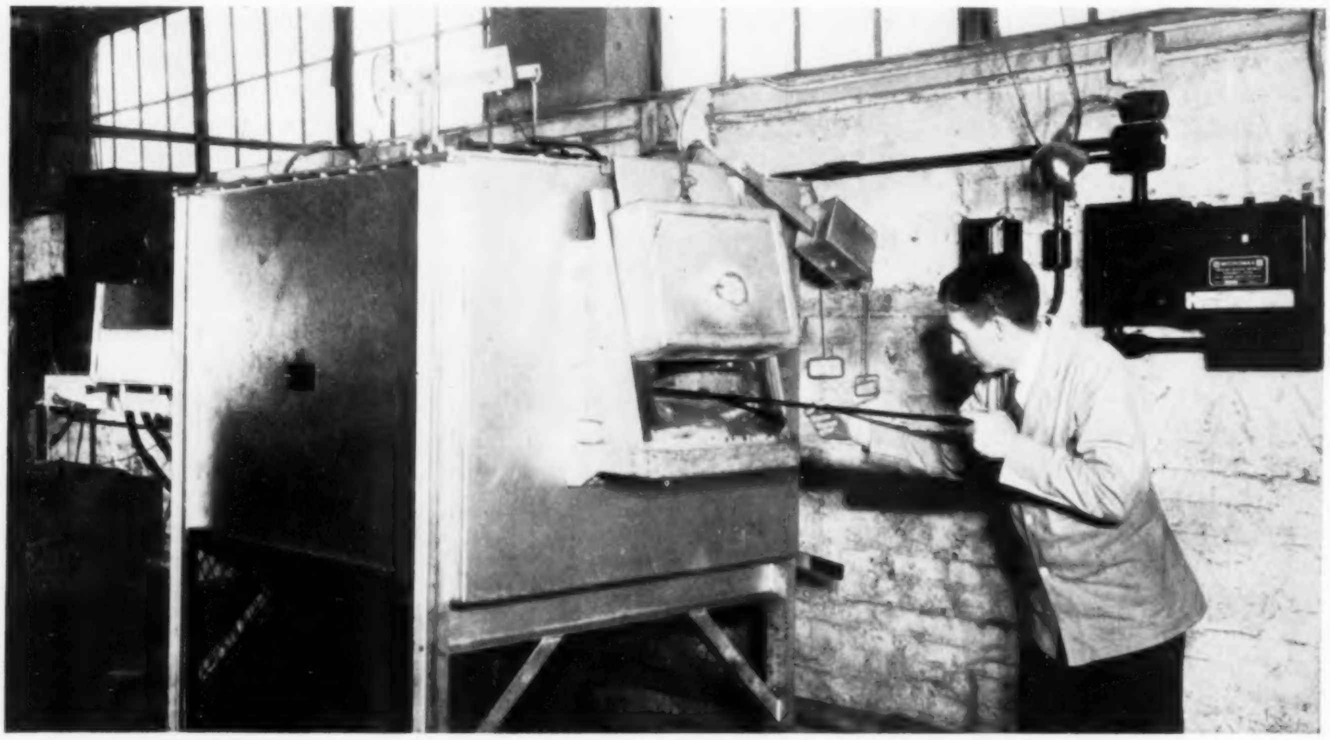
As in all other types of joints made by metal alloys (and it is even true of glued joints), the closer the original pieces are placed together and the thinner the filling material, the stronger is the union. Copper will penetrate riveted surfaces in contact at least four inches.

Automatic Device Made by General Electric Co. Which Mixes City and Natural Gas and Converts Them Into a Reducing Atmosphere by Partial Combustion (200 cu.ft. per hr.)



The box type of furnace used for these copper brazing applications was built by General Electric Co. for continuous services up to 2100° F. It is provided with refractory hearth plates and heavy ribbon resistors wound in short loops. Resistors hang on refractory hangers and spacers; the furnace also has a refractory door between the heating and cooling chambers. Thick and efficient insulation makes for economical operation; the electrical rating is 20 k.w. The door opening is 12 in. wide and 6 in. high. One tray $11\frac{1}{2}$ in. wide and 22 in. long, can be accommodated in the heating chamber; two such trays fill the long cooling chamber.

Gas for the atmosphere in the furnace is supplied from a combustion type of controller for furnace atmospheres. In this machine, a mixture of city gas and natural gas is reformed with air, by partial combustion, to produce an inexpensive mixture of gases suitable for electric furnace brazing, bright annealing, or scale-free hardening. As shown in the view at the left, it is a compact, self-contained unit.



Operator Pushing a Tray of Completed Parts From the Heating Chamber Into the Cooling Chamber. (The cooling chamber is the rectangular box extending from the rear of the furnace)

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- Galvanometer free 100% of the time.
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The ideal Controller not only for industrial use, but for laboratories also. Do you want control to 0.1°, .01°, .001°? . . . . Ask us about this.

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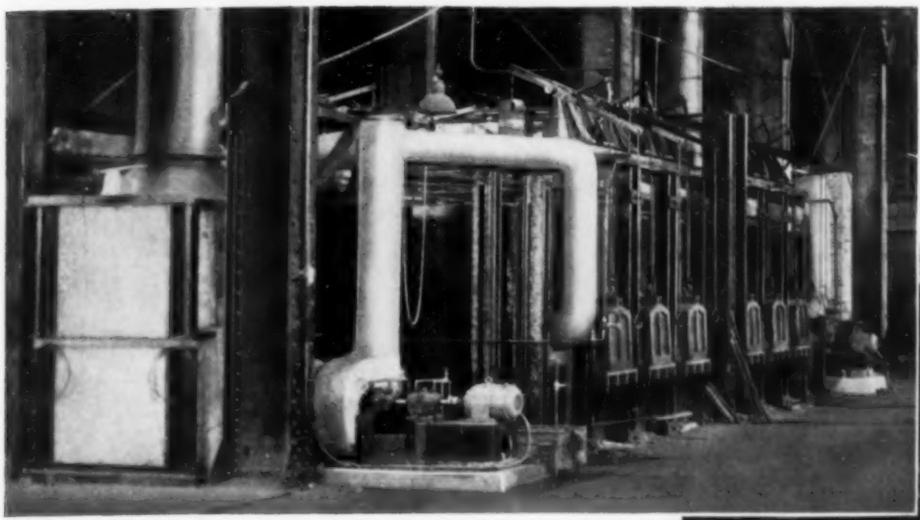
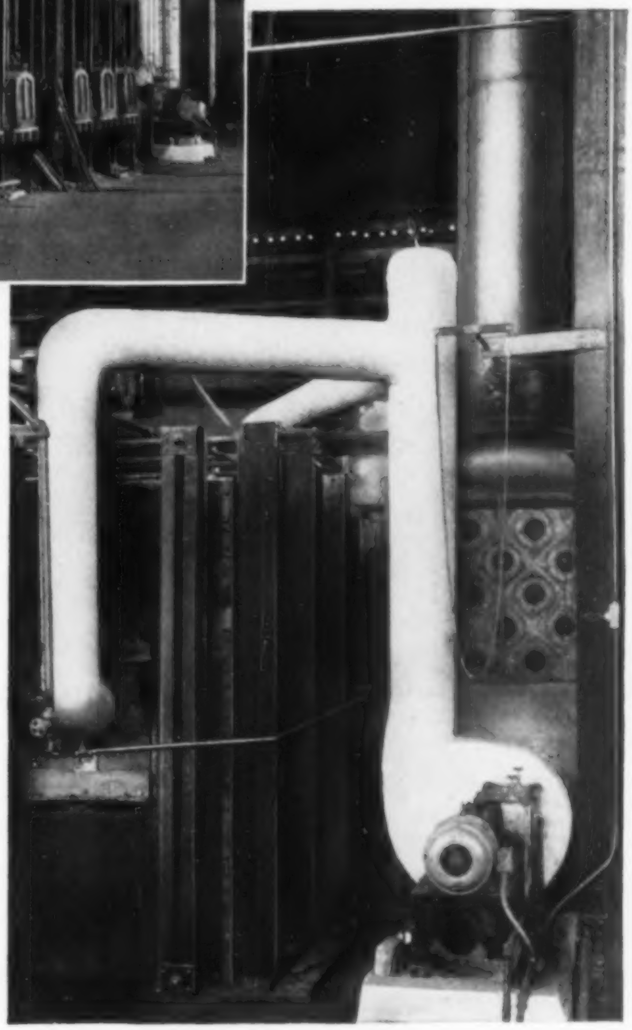


The twin chamber alloy billet heating furnace in the Dunkirk, N. Y. Plant of Ludlum Steel Company.



RECUPERATOR SAVES FUEL

at the Ludlum Steel Company

HERE ARE THE FACTS:

At the plant of Ludlum Steel Company, Dunkirk, N.Y., The Carborundum Company's Recuperators not only effect material fuel savings but also give closer control of temperature — faster heating — improved furnace atmosphere.

They operate a twin chamber alloy steel billet heating furnace. Both chambers are equipped with a recuperator, each using twenty-four tubes of "Carbofrax," the Carborundum Brand Silicon Carbide Refractory.

Air for combustion is preheated to 800° F. with the results noted above. The recuperators replace stack bases without requiring additional floor space.

The results are due to the use of the "Carbofrax" tubes — their extremely high heat conductivity — their long life — plus the perfected design of The Carborundum Company's Recuperator.

Complete engineering data giving details regarding application of the recuperators to various types of furnaces sent on request.

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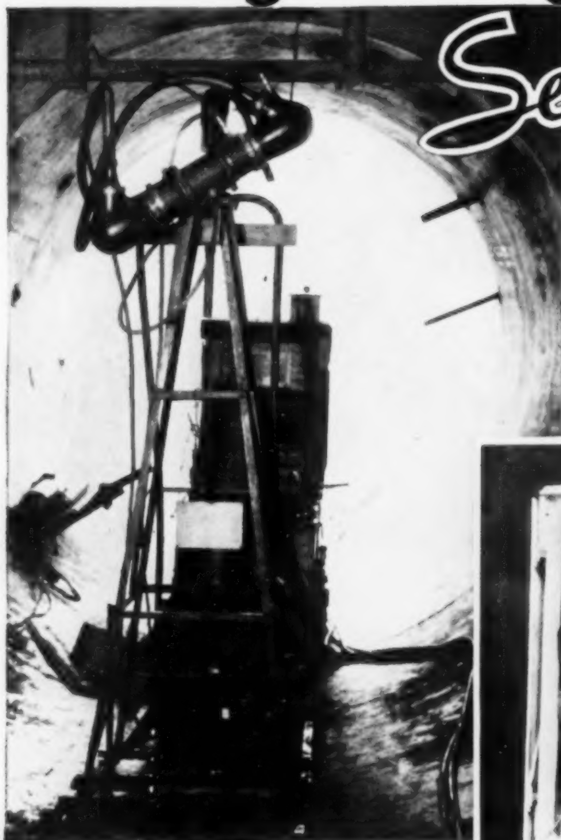
Chicago Bridge and Iron Works *Selects* G-E X-RAY UNIT for TVA Project



Operator's Control Cabin

● With government specifications calling for a strictly Class I job on the pipes for Norris Dam, the Chicago Bridge and Iron Works faced a problem of field-welding 20-ft. diameter tubes, and of inspecting these welds radiographically "on location." The illustrations show how they solved their inspection problem with the aid of General Electric mobile shock-proof x-ray equipment.

A high-voltage Coolidge x-ray tube, sealed in oil within a shock-proof casing, is swivel-mounted on a 10-ft. steel tower. This tower is positioned adjacent to each circumferential seam, which is then radiographed by rotating the x-ray tube to direct the rays through successive segments of the circular wall. Thus, with the x-ray tube centered 10 feet from the wall, a standardized technique has been established which enables the operator to make his "shots" in a thoroughly practical manner, rapidly and with unvarying precision.

It is interesting to note that, while this x-ray equipment is doing a specialized job, there is nothing special about its construction except the tube tower and the extra-length armored high-voltage cables connecting x-ray tube and control unit. It is not an experimental outfit full of "bugs" and "wrinkles," but a standard item of the G-E line, the KXC-3 Industrial X-Ray Unit, adapted to a particular duty. In other words, it is a well-tried and dependable inspection tool—powerful, rugged, weather-proof, altitude-proof and *shock-proof!*

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Cuts Forge Furnace Fuel Costs 84% Production Increased 55%

These savings, secured by a nationally-known farm implement manufacturer through the installation of B&W Insulating Firebrick in a gas-fired forge furnace, are typical of the unusual reductions in operating costs that may be effected in furnaces of this type.

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By saving 160 minutes of time and 1217 cu. ft. of gas during each heating-up period of a tool-heating furnace, B&W Insulating Firebrick saved, for a progressive drill manufacturer, $561.00 annually, as well as 800 hours or one hundred working days!

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HERE IS A NEW SOURCE OF SAVINGS *For* YOU

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Savings as substantial as those summarized above can be effected in your industrial-furnace operating costs . . . and simply by replacing firebrick linings with those constructed of Babcock & Wilcox Insulating Firebrick.

Both B&W K-26 and K-30 Insulating Firebrick (for temperatures up to 2600 and 3000 deg. fahr. respectively), not only possess the many advantages of highly efficient insulators but, due to their high fusion points, freedom from shrinkage, and inherent ability to support loads, may be used as the furnace structure directly exposed to heat.

The resultant savings in time and fuel, and the attendant increases in production are sufficient to justify a thorough investigation of this material.

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R-28

NITRIDING

(Cont. from page 43) done in the Research Institute for Aircraft Metals under Professor Akimov's direction may therefore be of interest.

We worked on two steels, each containing about 0.25% carbon, 1.50% chromium, 0.40% molybdenum, 0.50% manganese and 0.50% silicon. One however, had 0.70% aluminum whereas the other had 0.20% vanadium. About 50 hr. at 950° F. was required to get a case 0.016 to 0.020 in. thick on these steels, and only about 25% of the ammonia was dissociated. If the time is shorter the case is too thin. If the temperature is raised, the depth increases but the case becomes brittle.

Our first experiments consisted of a two-stage heat starting with 930° F. for a certain time and then raising it for a period to 1100° F. in one series, and to 1200° F. in another, and then slowly cooling in the furnace. Either program considerably increased the depth of case in the aluminum steel without reducing the surface hardness, but the outer layer was embrittled (as judged by the appearance of the impression in the Vickers hardness test and by compressing small cylinders). Reversing the cycle (first high temperature, then a soak at 930° F.) gives the same improvement in depth of case, but the surface hardness is too low.

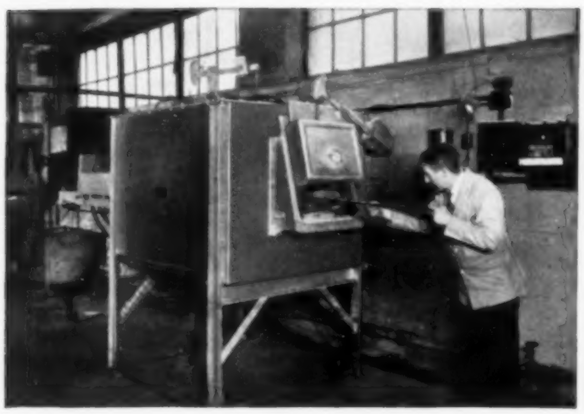
The vanadium steel (aluminum free) was unsatisfactory in either program.

Acting on the assumption that the concentration of nitrogen at the surface and its speed of inward diffusion are roughly proportional to the temperature we tried a three-stage process. In the first stage the temperature of 930° F. was indicated as determining the extent of nitride dispersion. In the second stage at 1100° or 1200° F. a high nitrogen content was built up at the surface, and the speed of diffusion inward was accelerated. In the third stage at 930° F. the rate of saturation of the outer layers with nitrogen is slower than the rate of diffusion, and thus reduces the concentration gradient and the brittleness of the surface.

Parts are being nitrided commercially by this process in one-half to one-third the time required at 900° F., and 65 to 70% of the ammonia is dissociated. There is a more gradual decrease in hardness from the surface to the core, and the surface itself is not brittle.

J. E. Kontorovich

How Union Special Machine Co. Cut Production Costs and Improved These Parts with G-E Electric-Furnace Brazing



THE Union Special Machine Co., Chicago, maker of industrial sewing machines, cut production costs and improved parts like those at the right with G-E electric-furnace brazing. Formerly these parts were riveted, pinned, torch-brazed, or machined from solid stock. Service costs, however, were high. The vibration caused by the high operating speeds of these machines (5000 to 6000 stitches per minute) often worked the fabricated parts loose.

G-E electric-furnace brazing has given these and other sewing-machine parts, joints that are strong, ductile, and have great resistance to vibration. Production and service costs have been lowered, and customer satisfaction increased.

Electric-furnace brazing is simple and economical. Brazing metal, in the form of wire or paste, is applied to the parts during assembly. A G-E controlled-atmosphere electric furnace does the rest. It brazes clean, neat-appearing assemblies, producing joints that are uniformly strong, tight, and ductile. The coupon below will bring you complete information.

When this tension release was riveted, service costs were high because vibration worked the joints loose. Now electric-furnace brazed. Results: lower service costs and strong, ductile, vibration-resisting joints

This bevel gear was formerly cut from solid bar stock. Now small gears are simply pressed on the shaft and electric-furnace brazed. Results: time and money saved by reducing machining and material costs

The Union Special Machine Co. formerly machined this main shaft (shown ½ size) from solid bar stock. Flanged end now electric-furnace brazed, saving time and money by eliminating much machine work

Bearing formerly torch-brazed to this "pressure foot." Now electric-furnace brazed, saving money by decreasing rejects, eliminating cleaning operations, and making assemblies that are uniformly strong

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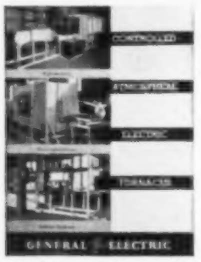

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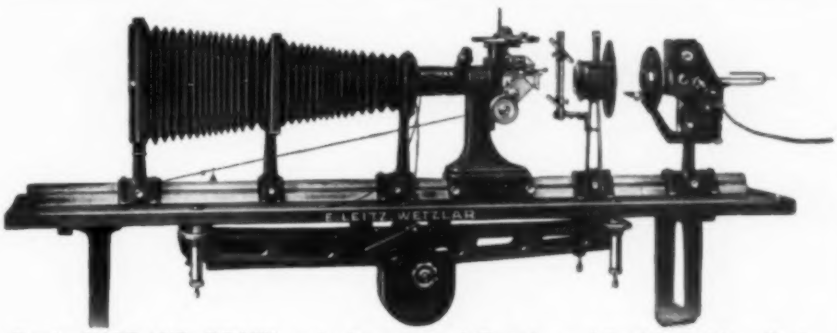

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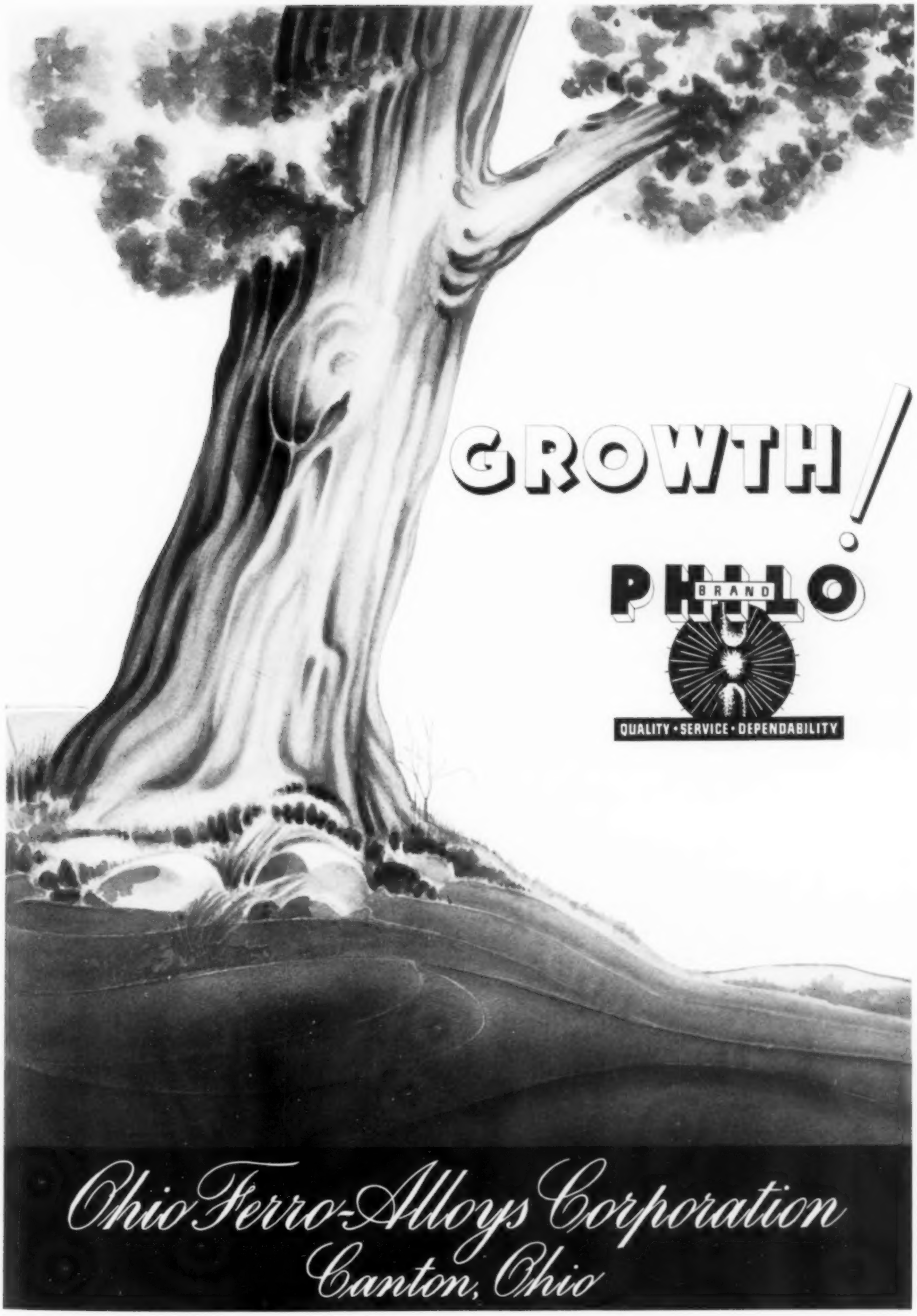
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CARBURIZING

Handling of hot compound during this operation without creating a heat and dust nuisance is sometimes a problem. If parts are of large size (one to a container, or a few wired together) they can be hooked out and quenched, and the cover replaced. On the other hand, small parts are frequently carburized in compound which is to be discarded after the run.

A mixture of parts to be quenched and hot compound to be reclaimed is best separated by dumping the pot on an inclined chute whose bottom is a fine grizzly or perforated plate. This chute reaches from the mouth of the furnace to the quenching tank. If both compound and parts are dumped on this chute, the compound passes through the openings and the parts slide down into the oil quench. In some instances this separation is further facilitated through the use of a vibrator. The compound is caught in a box or hopper underneath, and this may be promptly covered, or the hot material may discharge by gravity through a pipe into a covered tank.

At times localized carburization is necessary and can be effected in various ways, the full details of which are given in the last edition of National Metals Handbook. A very common and popular means used is to copper plate or chromium plate the areas which are desired soft. Our experience is that chromium is far superior to copper. At other times mechanical means is resorted to, such as the use of studs and washers to insulate partially the bores of cylindrical parts; sheets of copper may cover the desired locations.

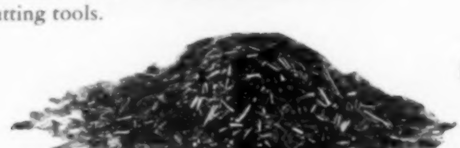
Other methods used are the application of specially prepared pastes (which experience in general has indicated to be very frequently unsatisfactory) or the use of sand, which in days past was very popular. There is considerable objection to sand, mainly due to the fact that it contaminates the carburizing compounds and at the same time is a poor heat conductor. Likewise it is only suitable for parts of certain shapes, such as flats which can be buried partway in sand in the bottom of the box, or a stack of tube-shaped parts which can have their centers filled.

Finally, the method frequently used is to allow extra stock at the point where carburization in the final product is not desired, and after carburization and slow cooling, machining off this excess, after which the parts can be hardened.

Types of steel to be used for hardening will naturally vary with the requirements for satisfactory service of the particular part involved. However, it is appropriate to state that, in general, carbon content below 0.15% would be desirable as having high ductility and good shock resisting qualities, but also having low core strength and poor machining qualities. Steels from 0.15 up to about 0.25% carbon would sacrifice some ductility and shock resisting qualities, but offer greater strength and better machining qualities. Further, it is well to say that for lower duties carbon steels are suitable, but for service where the duty is critical, alloy steels are extensively used. Grain size control is now frequently resorted to in carburizing grades of steel. It is found that the finer grain types, although offering slightly poorer machining qualities, more than offset this disadvantage by making it possible in many instances to quench directly from the carburizing temperature, eliminating thereby all subsequent hardening treatments and producing in the finished condition a product quite often superior to that obtained with the coarser grain types given the double hardening treatment after the carburizing operation.

Two Gas-Fired Furnaces for Carburizing in Rotary Retort. Furnace in background is in operating position; furnace in foreground has open retort and is in dumping position. (Courtesy American Gas Furnace Co.

These fine chips show why Anaconda "Special" Phosphor Bronze Rod does not foul cutting tools.



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Phosphor Bronze

American Brass Co. tells why Anaconda "Special" phosphor bronze can be used advantageously for bushings, bearings, gears, and other screw machine products. It is a truly free-cutting alloy and does not foul cutting tools. Other properties are given in this new edition of their booklet. Bulletin Fx-89.

Foundry Pyrometer

A leaflet from Pyrometer Instrument Co. briefly tells the advantages and operation of their Pyro Immersion Pyrometer for foundry use. This compact, self-contained instrument can be operated with one hand. Bulletin Fx-37.

Photocell Pyrometers

Recording potientiometers using a beam of light, a mirror galvanometer, and a photo-electric cell give instantaneous control with high sensitivity and accuracy. The different varieties made by C. J. Taglibue Mfg. Co. are described in a 16-page letter-size booklet. Bulletin Fx-62.

Alloy Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Deoscillator

How you can wipe out bothersome temperature lags at small expense is told by Foxboro Co. in a bulletin describing the Deoscillator, an auxiliary control unit which, when operated with the regular pyrometers, gives an anticipating effect to the control action. Bulletin Jx-21.

Pre-Heating Furnace

General heat treating operations up to 1900° F., pre-heating of high speed steel, annealing and firing of glass are some of the applications listed in American Electric Furnace Co.'s folder on their new model B-20 furnace. Bulletin Jx-2.

Neophot

"Neophot" is the name of a new metallograph of radically new design and universal adaptability. Observation and photography at 50 to 2000 $\times$ in bright field, dark field, and polarized light are possible with this instrument. A pamphlet distributed by Carl Zeiss, Inc., gives its applications and features and is well illustrated with beautiful samples of micrographic work. Bulletin Jx-28.

Dark Room Layout

A novel card 9½x13 in. containing suggested arrangements for a photomicrographic dark room has been designed by Bausch & Lomb. Costs for installation are estimated, and on the reverse side are printed rules for using the dark room. Bulletin Jx-35.

Radium Radiography

Advantages of portability, ease of application and manipulation in examination of castings, forgings, molds, weldings, and assemblies are attributed to radium for industrial radiography. Details are given in a booklet issued by Radon Co. Bulletin Jx-56.

Blast Cleaning

A centrifugal machine which cleans castings without the use of compressed air is the subject of Pangborn Corporation's new folder. How and why 1800 lb. of castings can be cleaned in 8 min. at low cost is told. Bulletin Jx-68.

Electric Furnaces

A wealth of information on controlled atmosphere electric furnaces is contained in General Electric Co.'s booklet by that name. Detailed data are given on electric brazing in particular. Bulletin Jx-60.

Multiple Tables

Ten convenient and simple tables in this booklet by Timken Steel & Tube enable the steel user to tell at a glance either how long his stock must be to furnish a definite number of multiples, or how many multiples can be cut from a given length of stock. Bulletin Dc-71.

Carburizing Boxes

Driver-Harris Co. devotes a folder to Nichrome cast carburizing boxes. Physical properties at room temperature and under operating conditions are given, as are the advantages of Nichrome castings for such service. Bulletin Jr-19.

Fast-Cutting Steel

Bliss & Laughlin, Inc., offer an interesting technical folder on Ultra-Cut Steel, giving performance records of this high-speed screw stock on automatic screw machines. Physical data and microstructures are presented. Bulletin Ob-42.

Hard Carbide

An extremely interesting little booklet describes "the hardest material ever produced by man for commercial use." This is boron carbide, and its manufacture, properties, and uses as an abrasive and as a wear resisting material are told by Norton Co. Bulletin Dc-88.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

New Hardening Method

All three vital factors in correct hardening are completely controlled by the new Vapocarb Hump method of hardening, which is well described in a Leeds & Northrup bulletin. The three factors are: Quench point, rate of heating, and furnace atmosphere. Complete details are given in Bulletin No-46.

Aluminum Alloys

Working facts on aluminum — the properties and heat treatment of both cast and wrought alloys — are briefed for the manufacturer and designer in a booklet by Aluminum Co. of America. An appendix gives tables of physical properties, forms and sizes available. Bulletin Dc-54.

Air for Furnaces

Users of gas or oil-fired furnaces know the necessity for a dependable source of large volumes of air at low pressures. A generously illustrated folder of Spencer Turbine Co. shows why their Turbo-Compressors give unfailing, economical air service. Bulletin Mr-70.

Sheffield Steels

Wm. Jessop & Sons, Inc., have a booklet which tells why a special anneal and a proper balancing of carbon, manganese and tungsten combine to make Sheffield Superior oil hardening steel non-distorting and easily machinable. Bulletin Jn-61.

Molybdenum in 1934

Climax Molybdenum Co. presents their annual book giving new developments in molybdenum, particularly as an alloy with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Dc-4.

Atmosphere Furnaces

An interesting folder of Surface Combustion Corp. gives performance data on their atmosphere furnaces in actual production bright annealing of ferrous and non-ferrous metals and carburizing, nitriding, forging and hardening without scale. Bulletin De-51.

Stainless Steel Uses

The wide range of applications of Allegheny Metal, best known of Allegheny Steel Co.'s corrosion and heat resistant steels, is pictorially covered in a new and interesting booklet. Bulletin Ob-92.

Manual of Pyrometry

Brown Instrument Co. offers an elaborate manual which describes the 50 exclusive features of their potentiometer pyrometer. The book will greatly interest those who must maintain accurate temperature. Bulletin Jr-3.

Localized Heat Treating

American Gas Furnace Co. offers information on production machines for localized hardening, tempering or annealing of tools, saws, springs, screws and machine parts of all kinds, using gas as fuel. Bulletin Ag-11.

Bright Annealing

Electric Furnace Co. tells about their controlled atmosphere furnaces for continuous deoxidize annealing, bright normalizing and annealing ferrous and non-ferrous metals. Work comes clean, bright and dry from these furnaces. Bulletin No-30.

Liquid Carburizing

E. F. Houghton's Perliton liquid carburizer is the subject of a 23-page booklet. Depth of case, speed of penetration, and other results are well illustrated with graphs and photomicrographs. Nv-38.

Shielded Arc Welding

Lincoln Electric Co. offers a very fine descriptive booklet describing the process of welding with a shielded arc. Text and illustrations are designed to acquaint engineers with the possibilities of the process. Bulletin Ob-10.

Sheet Iron Primer

The fifth edition of Republic's handsome 64-page booklet which tells the story of modern sheet iron in simple, non-technical language is now available. Gage tables and an interesting glossary of metallurgical terms are included. Bulletin Dc-8.

Nickel Cast Iron's Uses

The role of nickel and nickel-chromium cast iron parts in such applications as fabricating sheet metal, pressing and forging is interestingly explained in a new pamphlet of International Nickel Co. Bulletin Ag-45.

Tempering Furnace

Technical details and operating data on Lindberg Steel Treating Co.'s new Cyclone electric tempering furnace, which has shown a remarkable performance record in steel treating operations, are given in Bulletin Fx-66.

Hardness Testing

Men interested in hardness testing may find it worth while to read the recent catalog of Wilson Mechanical Instrument Co. which describes the latest design of Rockwell hardness testers and auxiliary work supports. Bulletin Sp-22.

Carbonol Process

The Carbonol process of carburizing is described in detail in a folder of Hevi Duty Electric Co. Results are said to be quicker, cleaner and better cases at very low cost. Bulletin Jy-44.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

X-Rays in Industry

General Electric X-Ray Co. has available a profusely illustrated brochure which gives the complete story of the industrial applications of X-Rays, the modern inspection tool. Bulletin Ma-6.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Cold Drawn Shapes

Many applications of cold drawn squares and flats are enumerated by Union Drawn Steel Co. in this folder. Sizes, grades of finish, and compositions available are listed. Nv-83.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Reports on Firebrick

Babcock and Wilcox Company offer a very complete set of Service Reports on Insulating Firebrick. These reports contain valuable data on adaptability of refractories and savings possible. Bulletin Ob-75.

Welding Rods

Linde Air Products Co. has published an attractive book which describes in clear, non-technical language the properties, characteristics, and uses of every type of Oxweld welding rod. A fund of reliable general information on welding rods is an important feature of the book. Bulletin Jr-63.

Metallograph

A new 36-page booklet of E. Leitz, Inc., contains all information on the Leitz large Micro-Metallograph, MM 1. Excellent photomicrographs are reproduced to show its capacity. Special attention is given to the darkfield illumination feature. Bulletin Se-47.

Electric Furnaces

The electric furnaces made by Hoskins Mfg. Co. are well presented in their latest catalog. Contents include data on 17 types of furnaces and some valuable information on Chromel resistance wires and thermocouples. Bulletin Sp-24.

Properties of Stainless

Carpenter Steel Co. offers (to manufacturers in U. S. A. only) a handy pocket size slide chart which gives at a glance a summary of technical data on all Carpenter stainless steels. Bulletin Se-12.

Metal Progress
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